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INDUSTRIAL
FATIGUE RESEARCH BOARD.

REPORT NO. 50.

The Physiological Cost of the Muscular Movements involved in Barrow Work.

BY

G. P. CROWDEN, M.Sc., M.R.C.S., L.R.C.P.

63226

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PREFACE.

The continued introduction into industry of labour-saving devices, which has for many years been a notable feature in modern industrial development, has inevitably been associated with the gradual elimination of heavy manual operations and the retention only of manual operations involving light and dexterous work. In consequence of this tendency, the mental aspects of industrial work are becoming relatively more important than the bodily, but nevertheless there still remain many occupations, especially within the "heavy" industries, in which the demands made on the worker are mainly muscular. Amongst the commonest of these occupations is the conveyance of material in one or other of its different forms.

The carrying of loads by hand has already been the subject of two investigations conducted for the Board,* which have shown that the methods studied, irrespective of the actual load carried, can be ranked roughly in order of merit, depending mainly on the degree of displacement of the body necessary to bring the centre of gravity over the feet, the amount of chest fixation, muscular tension and local strain, and the extent of interference with the normal gait. In many industries, however, expecially where continuous transport is involved, loads are usually conveyed by truck or barrow, and the Board have therefore felt it desirable that the investigations referred to should be supplemented by a physiological study of the chief characteristics of barrow work.

The results of this investigation are included in the present report They are derived from a series of experiments in which the energy expended was measured in terms of the "physiological cost", or the excess of oxygen consumed, with subjects engaged in wheeling bricks, this particular form of barrow work having been selected partly on account of the prominent part played by it in the brick-making industry and partly to admit of ready measurement and adjustment of the load. Whilst the definiteness of the conclusions is limited by the small number of the subjects employed, the results are consistent amongst themselves and disclose several matters of practical interest.

In the first place, the experiments show that with a barrow of given design the most suitable conditions for wheeling are determined by two factors, namely the weight of the load and the arrangement of the load. For instance, with the usual type of barrow designed to contain 70 bricks, this number has been

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* The Effects of Posture and Rest in Muscular Work, by E. M. Bedale, M.A., and H. M. Vernon, M D —*Ind. Fat. Res. Bd. Report No. 29*

The Physique of Women in Industry (A Contribution towards the Determination of the Optimum Load), by E. P. Cathcart, F.R.S., and others —*Ind. Fat. Res. Bd Report No. 44.*

(28937A) Wt. 21140/532/ 488 1000 4/28 Harrow G.25

shown to be in fact the optimum load, if, but only if, the arrangement is such that the position of the centre of gravity corresponds with a downward pressure of about 15 lbs on the hands when the handles of the barrow are raised to the height of the straightened arm (p. 13), it follows from this that for ideal conditions the arrangement of the load should be adjusted according to the stature of the barrowman (p. 18) Secondly, it appears that stopping and starting the loaded barrow involves a relatively large expenditure of energy, so that the desirability of an uninterrupted run is clearly indicated (p 6). Thirdly, the height of the handle relatively to the man's stature is shown to be important, especially where the work consists of very short runs (as in the case of the press boys), since, if it is too low, an unnecessary expenditure of energy is involved in raising it to the balance height (p. 11) Lastly, the energy expenditure is shown to be influenced by the speed of wheeling, the most favourable being a normal brisk walk (p 14) It is of special interest to note, as an example of empirical attainment of the best conditions, that both the optimum load and the optimum speed indicated by the results of this investigation are those already usually adopted in practice.

On the basis of these conclusions certain improvements in barrow design have been suggested and recommendations made in regard to the distribution of the load to suit the stature of the worker. Also a simple routine procedure has been devised enabling the Works Foreman to advise each newly engaged man of the most economical arrangement of the load to be adopted (p. 18). As will be seen from the Appendix (p 19), barrows constructed and loaded in accordance with these suggestions have now been experimentally tested under practical conditions and found to be satisfactory

March 1928

THE PHYSIOLOGICAL COST OF THE MUSCULAR MOVEMENTS INVOLVED IN BARROW WORK.

By G. P. CROWDEN, M Sc., M.R.C.S , L.R.C P

(From the Physiological Department, University College, London).

("Thesis approved for the Degree of Master of Science in the University of London").

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General.

This paper deals with the physiological cost of certain types of human muscular movement as measured by oxygen consumption

The conditions which govern the efficiency of the individual in respect of these movements have been worked out experimentally.

The knowledge so acquired has enabled the factors influencing expenditure of energy, and indirectly human fatigue arising from such muscular movements, to be appraised and has led to definite suggestions which have been put to the test of works practice.

The muscular movements under investigation were those involved by heavy barrow work of the kind employed in the production of "Fletton" bricks which are manufactured in hundreds of millions annually in the Peterborough district. A single barrow worker will move approximately 10,000 burnt or finished bricks, or 8,000 unburnt or green bricks in a working day of nine hours. A finished brick weighs about 5¾ lbs. hence the worker transports over twenty-five tons of bricks from the kilns to the rail sidings in a day, through distances varying from 25 to 75 yards

A cycle of work involves the following stages :—

1. Loading the barrow in the kiln
2. Pushing the barrow from the kiln to the siding.
3. Unloading the barrow.
4. Returning to the kiln with the empty barrow.

The physiological cost of stage 2 of this cycle has been investigated in order to determine:

(*a*) the relative importance of the factors involving oxygen consumption on the part of the worker. (*b*) the optimum conditions under which such work may be performed

The methods of determining the oxygen consumption of the individual when doing muscular work, as elaborated by Professor A V. Hill and his co-workers(1), have been applied to the investigation of the energy expenditure involved in heavy barrow work of this kind Unskilled and skilled workers have been used as subjects.

Definitions.

The term "physiological cost" is intended to convey the idea of the actual cost of production of energy to the worker's body Oxygen is used by man in proportion to the amount of energy-producing substances burnt in his body, and therefore an accurate measurement of the oxygen absorbed from the air during a period of time, including both work and recovery, gives a reliable indication of the extent of the vital processes involved

The physiological cost of a given piece of work is the amount of oxygen used during work and recovery in excess of the amount used during an equal period of time, the subject being in the resting state

It might be pointed out that the method of measuring the oxygen cost of the work in this investigation is the only one available at present With exercise of this degree of severity it would be impossible to maintain the effort long enough for a steady state of oxygen consumption corresponding to the exercise to be reached. Moreover, the discontinuous nature of the process would prohibit any other known method of measurement

Experimental Procedure.

The majority of experiments were carried out between 9 a.m. and 1 p.m , and as a general routine the following procedure was adopted.

An experiment commenced about 2½ hours after a light breakfast. The subject adopted the resting sitting posture in a chair for a fore-period of 30 minutes after which a 10-minute collection of his expired air was made. He was then fitted with a 300 litre Douglas bag and on the given signal performed the pre-arranged piece of work, after which he again adopted the resting sitting posture. The expired air during exercise and recovery was collected for a period of 30 minutes, and finally a 10-minute collection was made in order to check his resting oxygen consumption

The experiments which were used for comparisons were all carried out in the same place The earlier experiments were carried out in the open, but it was found that owing to the variability of the weather and the cooling power of the air these were not satisfactory from the point of view of comparison except in certain cases Later experiments were carried out in a gymnasium where the temperature and cooling power of the air were practically constant The experiments with the skilled worker were carried out in a large hall where it was possible to get a longer lap length than before.

Barrow Design

A detailed description of the construction of the particular type of barrow used is unnecessary as this is made clear in Fig 1, which shows a barrow with a normal load of 70 burnt bricks arranged in the way invariably adopted by the workers As far as it has been possible to ascertain details of barrow design it appears that two types of barrow are in use, the difference being a slightly altered position of the axle in relation to the front of the loading platform as shown in Fig 2, *a*, *b* The barrow used was of type (*a*)

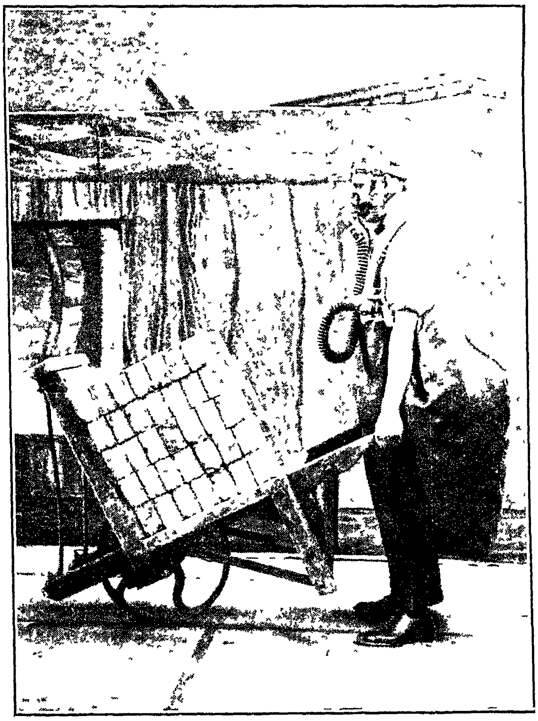

FIG 1 —70 Burnt Bricks Normal load and arrangement

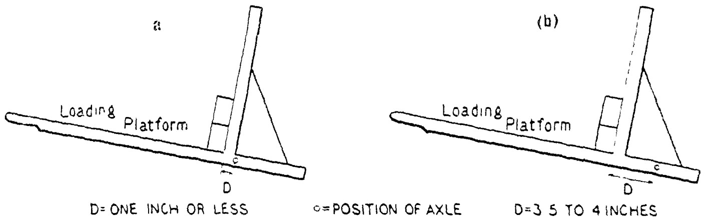

FIG 2 —Types of Barrow now in use

Factors involving Energy Expenditure

With this type of barrow there are three factors which involve expenditure of energy on the part of the worker when carrying out the second stage of the work cycle referred to above Each factor demands definite muscular movements by the worker, energy being expended as follows —

(i) In raising and lowering the handles—the Gravity Factor
(ii) In attaining speed and stopping—the Acceleration Factor
(iii) In maintaining the speed—the Velocity Factor

As the increase in the oxygen consumption of a worker is proportionate to his energy expenditure, it has been possible to determine the relative importance of each of these factors from the point of view of physiological cost

A series of experiments was conducted using a trained barrow worker, obtained through an Employment Exchange, as subject. The load carried was 70 finished bricks arranged as in Fig 1, namely, the normal load and arrangement The subject was told to push the barrow at what he felt to be a normal brisk walking pace, and to cover a definite distance in spurts of 10 metres

These results are shown in Table I.(a)

TABLE I (a) —*Physiological Cost of Wheeling 10 metres*

Pace.	Work done			Excess Oxygen used.	Notes
	Number of		Distance.		
	Starts	Stops			
			metres		
Normal brisk walk ..	5	5	50	3,190 cc	Distance covered in spurts of 10 metres.
,, ,, ,, .	10	10	100	6,580 cc	
,, ,, ,, .	10	10	100	6,220 cc.	
Mean value ..	1	1	10	639 cc	—

The subject was then instructed to complete three laps, namely, 150 metres, at the same pace but without any intermediate stops. These results are given in Table I (b).

TABLE I.(b).—*Physiological Cost of Wheeling 150 metres.*

Pace.	Work done			Excess Oxygen used.	Notes.
	Number of		Distance.		
	Starts.	Stops.			
			metres.		
Normal brisk walk ..	1	1	150	3,640 cc.	Distance covered in one spurt of 150 metres
,, ,, ,, .	1	1	150	3,480 cc	
Mean value ..	1	1	150	3,560 cc	—

The volume shown in this table as Excess Oxygen used is the total oxygen consumption of the worker during exercise and recovery less his resting oxygen consumption for an equal period of time

Taking the mean values for the excess oxygen consumption shown in this table it is evident that :—

1 start, 1 stop, 150 metres involves 3,560 cc oxygen cost.
1 ,, 1 ,, 10 ,, ,, 639 cc. ,, ,,
By difference 140 ,, ,, 2921 cc. ,, ,,
Hence 10 ,, ,, 208 cc. ,, ,,
Therefore 1 start and 1 stop involves 639—208 cc. ,, ,,
= 431 cc oxygen cost.

In a 50 metre barrow run the oxygen consumption in excess of the resting consumption would therefore be :—

Due to starting and stopping 431 cc. or 29·3 per cent
Due to pushing 50 metres (208 × 5) = 1,040 cc or 70·7 per cent.
Total = 1,471 cc.

The figures for oxygen consumption due to starting and stopping include the oxygen used as a result of raising and lowering the barrow handles, that is, they give the physiological cost of the Gravity and Acceleration factors combined. The cost of the Gravity factor was determined by experiments in which only the movements of raising and lowering the handles of the loaded barrow were performed. In these the subject was told to raise and lower the handles just as if he were about to start and stop pushing the barrow. The barrow was loaded as for the previous experiments and the movement was repeated twenty times in order to ensure a reasonably large consumption of oxygen and so minimise error.

The results were as follows :—

Work done.	Excess O_2 used.	O_2 per raising and lowering.
Handles raised and lowered 20 times	2,320 cc	116 cc
,, ,,	2,270 cc	113 cc
Mean value . .	2,295	114 cc.

O_2 consumption per start and stop (Gravity and Acceleration factors) = 431 cc

O_2 consumption per raising and lowering (Gravity factor) = 114 cc.

By difference : O_2 consumption for attaining speed and stopping (Acceleration factor) = 317 cc.

From these results the relative importance of the three factors—Gravity, Acceleration, and Velocity—can be expressed in terms of oxygen consumption whatever the distance covered, provided the velocity attained and maintained be that of a normal brisk walking pace For example, over a distance of 50 metres the figures would be :—

1. Gravity factor, raising and lowering handles, 114 cc or 7·75 per cent.
2. Acceleration factor, attaining speed and stopping, 317 cc. or 21·55 per cent.
3. Velocity factor, maintaining speed for 50 metres, 1,040 cc. or 70·7 per cent.

Total 1,471 cc. 100 per cent.

It follows that when the worker pushes the barrow over a distance of 50 yards, the track being horizontal and the surface being wooden boards, factors 1 and 2 account for approximately 30 per cent. of the total physiological cost. Evidently, therefore, if the worker has to stop once on such a journey, factors 1 and 2 will be automatically doubled and his oxygen consumption for the piece of work increased by approximately 30 per cent. With men of different stature, with barrows of slightly different design, with a track not uniformly horizontal or with a surface of steel plates (as often employed in the works), the relative values for these factors might be slightly different, but these results suffice to show the desirability, particularly in short runs, of an uninterrupted journey for the worker.

Effect of Training.

A barrow worker may be judged to be fully trained or classed as skilled when he can adequately control and balance the barrow with the minimum tension on his arms, while at the same time maintaining his body in the position which permits of maximum comfort and efficiency for the muscular movements involved *

The excess oxygen consumption of the worker for a definite piece of work has been determined at different stages of training Table II shows the effect of training on the physiological cost in the cases of three unskilled subjects, A, B, C. Subject D was a skilled worker who had been unemployed for some months. A fortnight elapsed between the two readings quoted for D and during that time he had practised a good deal with the particular load.

TABLE II—*Effect of Training on Physiological Cost*

Training.	A.	B.	C	D.
Nil	—	—	3,060 cc.	—
Very poor ..	3,960 cc.	3,175 cc.	2,750 cc.	—
Poor . ..	2,574 cc.	2,410 cc.	1,500 cc.	2,825 cc.
Fair	1,900 cc.	—	1,100 cc	1,240 cc.

The data given in this table which shows the effect of training on the physiological cost of a given piece of work indicate that in investigating such questions as optimum load the subject should not be trained or skilled in handling any particular load. If the subject were a skilled worker with one load as a result of many years' experience it would be necessary for the same degree of skill to be acquired for each load the relative physiological cost of which it is desired to determine ; for, without equal degrees of training a comparison of the results would be worthless.

This point of view on the value of experiments in which unskilled subjects are used has been emphasized by Cathcart in his foreword to Miss Bedale's paper on the energy expenditure of a woman carrying loads in different positions.(2)

Optimum Load.

The following experiments on the optimum load in this type of barrow work were carried out with an unskilled subject In order to eliminate the variations due to training from day to day the whole series of observations on different loads were made on one day and repeated in reverse order on a second occasion. The reverse order of loads on the second occasion was taken because it was thought that the practice given by the first loads might have affected the oxygen consumption for the later loads on the same morning.

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* With very unskilled workers the balancing of the barrow is probably an important factor influencing the oxygen consumption for a given piece of work, but with skilled men this is of less importance No doubt the acquirement of skill in balancing the barrow is one of the results of training, which accounts for the marked reduction in physiological cost to the worker even after very little practice.

TABLE III.—*Effect of Load on Physiological Cost*

Load.	40 Bricks.	50 Bricks.	60 Bricks	70 Bricks	75 Bricks
First occasion ..	2,250 cc.	2,574 cc.	3,500 cc.	2,560 cc	2,960 cc
Relative values ..	·879	1·005	1·36	1	1·15
Second occasion ..	1,420 cc	1,900 cc.	1,869 cc	1,300 cc.	—
Relative values ..	1·09	1·46	1·437	1	—

In all cases the distance covered was the same. The subject had trained between the first and second determinations which accounts for the lower level of oxygen consumption on the second occasion, and the fact that owing to variations in balance it is easier to become skilled with some loads than others must also be taken into account when considering these figures

The important point to note is that although on the second occasion the subject started at a load of 70 bricks and went on to 60, 50 and 40, yet the relative values for the oxygen consumption per load for 60 and 70 bricks are the same as on the first occasion when the order of loads was 40, 50, 60, 70. In each case the physiological cost for a load of 70 was less than that for 60 bricks, and even 50 bricks may involve a greater absolute consumption of oxygen than 70 bricks though both loads be transported over the same distance. The normal load of burnt bricks adopted by the workers is invariably 70 and this appears to be the optimum load for this type of barrow. Loads greater or less than 70 may involve increased oxygen consumption on the part of the worker because the balance of the barrow may be altered to his disadvantage.

Mechanics of Barrow Work.

Consideration of these results led to a detailed investigation of the mechanics of barrow work in order to determine the relationship between the tension on the worker's arms and :—

(1) The load.
(2) The height of the handles
(3) The arrangement of the load.

The measurement of the vertical tension on the arms at various heights of the handles and with various loads was made by means of a spring balance attached to a differential pulley block which enabled the handles to be raised to any desired height.

It was found that when the handles were suspended at a height equal to that of the subject's hands above the ground in the erect position, the curve showing the relationship between the tension on the worker's arms and load was remarkably similar.

to the curve of oxygen consumption and load Both curves together with the arrangement* and the balance height of the handles above the ground level for each load are shown in Fig 3

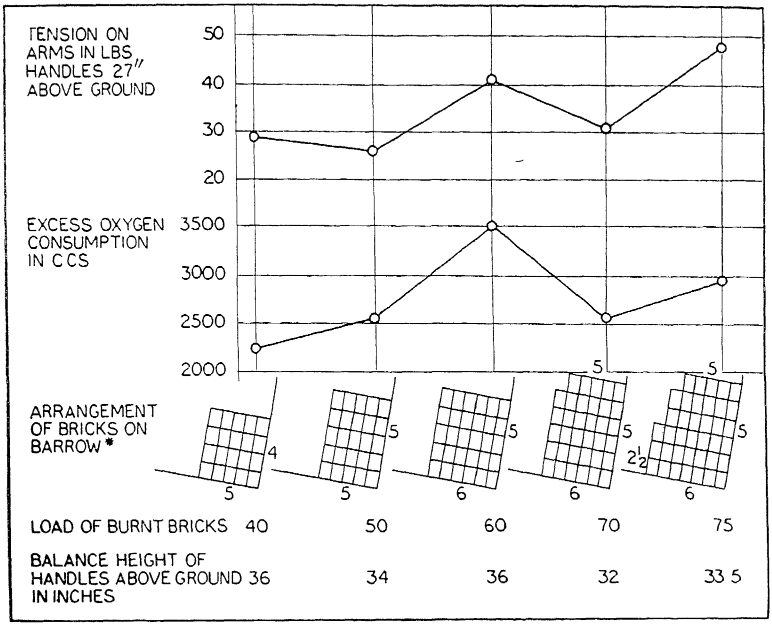

FIG 3 —Different arrangements of load compared

With untrained workers, therefore, the tension placed on their arms when holding the handles of the barrow at the natural height of their hands above the ground appears to bear some relationship to the physiological cost of the work An untrained worker tends to carry more weight on his arms than a trained man who has acquired the art of balancing the barrow In this connection it is interesting to bear in mind the work of Vernon (3) on the maximum lifting pull which can be exerted at various heights of the subject's hands above the ground level, also the investigations of Atzler (4) on the optimum height from which various weights may be lifted and to which they may be raised by operatives.

Owing to the construction of the barrow the tension on the arms decreases as the handles are raised, the minimum tension being when the load balances The optimum condition for the worker, however, is not necessarily that of holding the handles at the balance height, for to do so may mean the adoption of an uncomfortable posture necessitated by his stature. Attention has been called by various workers (2) (3) to the importance of posture in relation to physiological cost and fatigue, and it must be considered in this type of work

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* The diagrams of the arrangement of the load in this and in subsequent figures represent a side view of the loaded barrow The small numerals indicate the number of bricks stacked wide and high on one half of the loading platform For example 5 × 4 = 20 bricks on each half of the barrow = 40 bricks in all

From observing the methods of wheeling of both skilled and unskilled subjects of varying heights the following facts are evident —

(*a*) The worker must have perfect control over the barrow, particularly in view of its great weight when fully loaded—530 lbs

(*b*) Adequate control is not possible if the barrow tends to tip forwards Such a condition arises if the natural height of the worker's hands is greater than the balance height of the barrow-handles above the ground

By arranging the load in various ways, the balance height of the handles can be adjusted to suit the stature of the worker, and unless this adjustment be made the physiological cost of doing the work will be increased in one or both of the following ways —

(1) By involving an unnecessarily large tension on the arms, e g, a short worker with load having a high balance height

(2) By causing the adoption of an uncomfortable posture, e g, a tall worker with a load having a low balance height.

The individual automatically adjusts his body in order to maintain control of the barrow, and this involves increased oxygen consumption

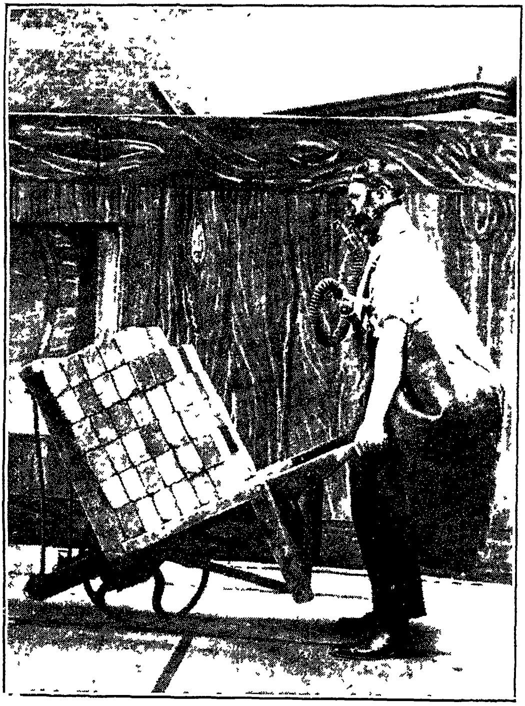


FIG 4.—70 Burnt Bricks Showing arrangement for short worker

For example in the case of two subjects A and D. Subject A, height 5 ft. 8 in., hands 30 in. above ground when arms hang vertically. Subject D, height 6 ft. 2 in., hands 33 in. above ground when arms hang vertically. A had perfect control over a load of 70 bricks arranged as in the photograph, Fig 4. D had difficulty in balancing this arrangement. He had to adopt a crouching position when wheeling.

The barrow balanced when the handle grips were raised to 32 in. above the ground. At 30 in. the tension on A's arms was approximately 15 lb. At 33 in. D had to prevent the barrow from tipping forwards.

In the works the arrangement shown in Fig 1 is invariably adopted. It is, therefore, of interest to consider the working conditions for this arrangement in the case of these two subjects of different stature

With this arrangement, namely bricks stacked five high and seven wide on each half of the loading platform, the barrow balances when the handle grips are 36 in above the ground. At 30 in. subject A had to bear a tension on his arms of 46 lb. At 33 in. D had a tension on his arms of approximately 18 lbs. Subject A felt this arrangement much more strenuous for him than the arrangement in Fig. 4, whereas it was a comfortable arrangement for D.

Work done in raising Handles.—From the data obtained when investigating the relationship between the height of the handles and the tension on the worker's arms, the absolute amount of work done in raising the handles with different loads and with different arrangements of the same load can be calculated.

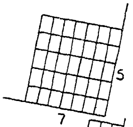
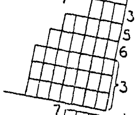
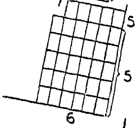
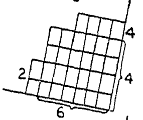
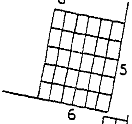
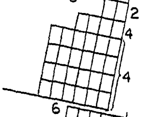
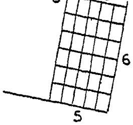
Over very short distances the work done in raising and lowering the handles when starting and stopping may account for a large proportion of the total energy expended by the worker. For example, in the case of a run of 10 yards, it would be equivalent to approximately 18 per cent. of the excess oxygen consumption, and where, as is often the case, the barrows, after being loaded at the presses, are moved to one side by the press boys, to a much larger percentage.

The following table gives the amount of work which has to be done in raising the barrow handles to the balance level in the case of various loads and arrangements. In each case the handles had to be raised from 17 in. to a variable height depending on the particular load and arrangement.

This table shows that there is a great variation in the amount of work done. It is possible that by lengthening the legs of the barrow, and so approximating the standing height to the balance height the work involved in lifting from standing height to balance height, might be reduced. The legs of the barrow, however, must not only have sufficient clearance of the ground when wheeling, but must also be sufficiently short to prevent it being tipped over when starting.

TABLE IV.—*Work done in raising Barrow Handles.*

TABLE IV.

	Load Arrangement.		Balance Height Inches	Work done in raising handles Foot. lbs
Load : 70 Burnt bricks		(1)	36	89·8
		(2)	34½	76·5
		(3)	32	57·8
Load : 60 Green bricks.		(1)	35½	85·9
		(2)	34¼	75·8
		(3)	32¾	62·6
		(4)	30¼	47·2

A similar economy of effort might also be achieved by slightly altering the position of the axle in relation to the front of the loading platform, the length of the barrow handles being adjusted accordingly, so that their balance level would be at a convenient height for the worker.

Optimum Arrangement.

It became evident from these investigations of the mechanical factors involved in barrow work that the load of 70 bricks is not necessarily the optimum load unless it is distributed in accordance with the optimum arrangement as determined entirely by the stature of the particular worker concerned. The optimum arrangement for any particular worker appears to be one which almost balances when the handle grips are raised to the height of the worker's hands when he stands erect with his arms hanging vertically. The vertical tension on the worker's arms in this position should be about 15 lbs. if adequate control of the barrow is to be maintained From the data given in Table IV for the type of barrow employed in this experiment, any worker of ordinary stature could be informed which arrangement would be the best for him to adopt, the only measurement required being the height of the middle of the palms of his hands above the ground when his arms hang vertically by his side.

In certain works it is the practice for groups of men to adopt different arrangements for green bricks, namely, 1, 2 or 3 in Table IV, but 70 burnt bricks are invariably loaded five high and seven wide.

A few experiments were done with loads of green bricks using the skilled worker D as subject. All the three arrangements, 1, 2, 3, figured above, were tried

The subject found that he could handle arrangement 2 better than the others, namely, the arrangement five high and six wide on each half of the barrow. It is very interesting to note that the balance height for this arrangement is 34¼ in. which is practically the same as for the hod arrangement No. 2, which he found most convenient for burnt bricks.

It would be easy to determine, once and for all, the balance height of the handles for any given type of barrow for three or four different arrangements of the normal loads of 70 burnt or 60 green bricks and as a working rule the optimum arrangement recommended for the worker might be one the balance height of which is one or two inches greater than the height of the palms of his hands above the ground when his arms hang vertically by his side. With such an arrangement the worker should be able to adopt a comfortable posture, while at the same time having sufficient tension on his arms to give him adequate controlling purchase over the barrow.

Optimum Rate of Wheeling.

A series of experiments to determine the optimum rate of wheeling were carried out, a skilled worker being employed as subject. Four different rates were selected, and a complete experiment consisted of the determination of the excess oxygen consumption of the worker for identical amounts of useful work when performed at those rates In this case, as in the case of optimum load, it was necessary that all data for comparison should be obtained at one experimental sitting because of the uncertainty of the subject being in exactly the same state of training or practice from day to day. Definite absolute rates of wheeling were not imposed on the subject, but in order to disturb the subject as little as possible by detracting his attention from wheeling and balancing the barrow, he was told to go at rates which he himself felt were as follows :—

(1) A deliberately slow walk.
(2) A normal brisk walking pace.
(3) A very quick walk.
(4) A gentle run.

The excess oxygen used for the same piece of work when done at each of these rates was determined, the whole of the expired air during exercise and recovery being collected in each case. Owing to the strenuous nature of the work no attempt was made to get the worker into a steady state for any of these rates. The load employed was the normal one of 70 burnt bricks arranged in various ways. It was found that the actual arrangement of the load did not affect the relative values for the physiological cost of wheeling at these rates.

The following table gives the results for three complete experiments :—

TABLE V.—*Physiological Cost of Wheeling Barrow at Various Rates.*

	Slow Walk.	Normal Brisk Walk.	Very Quick Walk.	Gentle Run.
Excess O_2	2,520 cc.	2,480 cc.	4,040 cc.	3,660 cc
Relative values ..	1·01	1	1·63	1·47
Excess O_2	2,515 cc	2,280 cc.	4,405 cc.	3,887 cc.
Relative values ..	1·1	1	1·77	1·7
Excess O_2	1,560 cc	1,240 cc	2,040 cc	1,960 cc.
Relative values .	1 26	1	1·64	1·58
Mean relative values	1·12	1	1·68	1·58

From these results it appears that the optimum rate for wheeling a barrow, from the point of view of physiological cost, is a normal brisk walking pace. If the worker goes deliberately slowly, the physiological cost is increased. If he forces his walking pace to a maximum the cost is very much increased, the excess oxygen consumption for the given piece of work being greater for this rate than for any of the other rates investigated. The physiological cost is greater for very quick walking than for gentle running

Recovery after Wheeling.

The normal work cycle at a brickworks as referred to in the earlier part of this paper automatically ensures that the worker after wheeling the loaded barrow, changes his posture and performs totally different types of muscular movement for a few minutes. This gives him almost all the advantages of a rest pause, the importance of which has been made clear by the investigations of Vernon (3).

Some recent work of R. M. Sargent (5) indicates that 90 per cent. of the recovery process, as determined by oxygen consumption, may be completed in from 5 to 10 minutes after the cessation of exercise of about this degree of severity.

Hence, if the worker conforms to the conditions of optimum efficiency in regard to load, arrangement, and speed, the alternation of the stages in the work cycle may enable him to maintain a high efficiency over a long period.

Summary

1. The physiological cost as indicated by the oxygen consumption of the worker has been determined for the various types of movement entailed by heavy barrow work. The relative cost to the worker of raising and lowering the barrow handles, attaining speed and stopping and of maintaining speed varies with the distance covered and the speed, but the importance of an uninterrupted run, particularly when 50 yards or less, is made evident One stoppage in such a run may involve 30 per cent. increase in the oxygen cost of the work.

2 The effect of training on the oxygen cost of a given piece of work has been investigated.

3. The conditions for maximum efficiency on the part of the barrow worker have been worked out by experiment and observation, and after taking into account the state of training or skill of the worker and the design of the barrow, may be stated to be :—

(*a*) The possession of adequate control and balance with the minimum tension on his arms.

(*b*) The adoption of the arrangement of the load which entails the minimum expenditure of energy and at the same time enables the worker to assume the optimum posture for comfort.

(*c*) The employment of the optimum load, which may very well be the normal load now adopted in the works provided that it be arranged in the optimum way as determined by the stature of the individual worker. Suggestions are made for the application of this condition in works practice, namely, the use of the measurement of the height of the worker's hands above the ground as an index of the optimum arrangement for him to employ.

(*d*) The adoption of the optimum rate of pushing a barrow, namely, the normal brisk walking pace of the individual worker.

4. Certain improvements in barrow design have been suggested.

5. The recovery of the worker after the strenuous work of wheeling has been considered, and it is thought that the automatic alternation of stages in the normal work cycle provides the worker with almost all the advantages of rest pauses, particularly if he performs the work in accordance with the conditions stated under (3) above.

My thanks are due to Professor A. V. Hill for very kind advice and criticism, and to the Medical Research Council for a grant enabling this work to be undertaken for the Industrial Fatigue Research Board.

I also wish to express my thanks to Messrs. Itter, Ltd., Brick Manufacturers, for their kindness in supplying me with the barrow and bricks, and for the interest they have shown in the investigation as it progressed.

REFERENCES.

(1) A V Hill, C. N. H. Long and H. Lupton *Proc. Roy. Soc. B*, vol. 97, 1924.

(2) E. M Bedale. *Report No.* 29, 1924, *Industrial Fatigue Research Board.*

(3) H. M Vernon. Ibid.

(4) E. Atzler. *Die Naturwissenschaften*, 1924. *Jahrg*, 12, *Heft* 47.

(5) R. M. Sargent. *Proc. Roy. Soc. B*, vol. 100, 1926.

APPENDIX.

APPLICATION TO WORKS PRACTICE.

The routine working conditions at the brickworks of Messrs. Itter, Ltd., at King's Dyke, near Peterborough, were studied. A demonstration was given to the employees and the factors governing the expenditure of energy by the worker in the various movements involved in barrow work were explained. In conjunction with the works' manager and foreman, trials were made to determine the optimum length for the legs of the barrows and an investigation of the practical value of the recommendations in regard to optimum arrangement of load for workers of different stature was carried out.

DEFINITIONS.

Press Boys.—Boys of 14–16 years of age who load unburnt bricks on to the barrows as they come from the presses. (*See* Fig. 5.)

Setters.—Men who wheel the loaded barrows of unburnt bricks from the presses to the kilns and stack the bricks there to be burnt Setters use different barrows as they are loaded at the presses.

Drawers.—Men who possess and load their own barrows with burnt bricks in the kilns and take them to the rail siding where they unload the bricks and stack them in the trucks.

Palm-height.—The height above the ground of the middle of the palms of the worker's hands when he stands erect with his arms hanging vertically.

Balance-height.—The height of the tip of the barrow handles above the ground when the load balances about the axle.

PRACTICAL TRIALS.

Barrow Design.—The legs of six barrows were lengthened from 14 in. or 16 in. to 20 in. and tried by the press boys and setters. (*See* Figs. 6, 7.) The boys liked the change and found the barrows much easier to handle, but if the legs of the barrow were longer than 18 in. the setters experienced difficulty in turning corners, difficulty in wheeling if the weather was wet, and difficulty in unloading the green bricks in the kilns as the bricks tended to slip backwards when drawn forward by hand to be lifted.

On the other hand, if the legs of the barrow are less than 18 in. long, an unnecessarily large lifting strain is placed on the press boys and the setters when starting and stopping.

The legs were accordingly shortened first to 19 in. and then to 18 in., the latter being the best length for the stature of the average setter. Setters use different barrows. Drawers always use their own particular barrows. It was, therefore, necessary to determine the optimum barrow design for the setter of average stature (Fig. 7.)

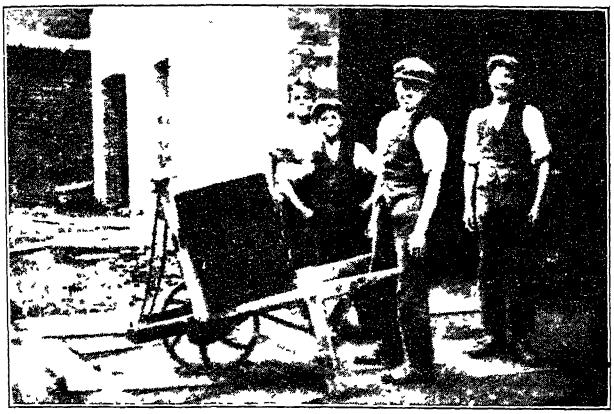


FIG 5 —Photograph of press boys with barrow with lengthened legs

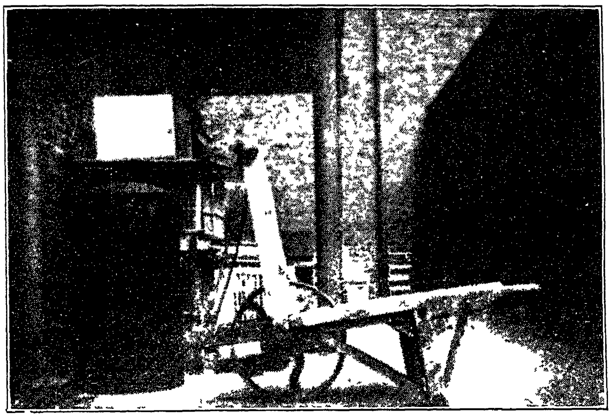


FIG 6 —Photograph of barrow before lengthening legs

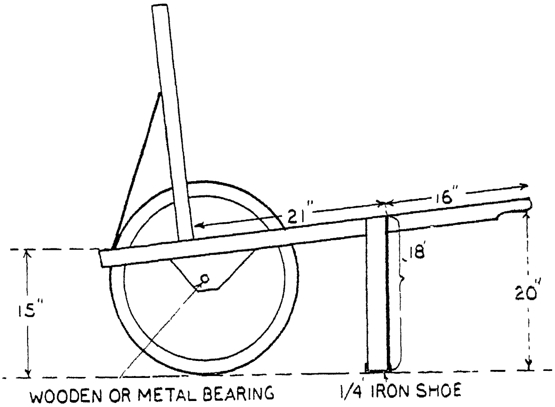


FIG. 7

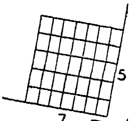
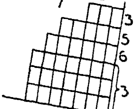
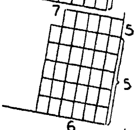
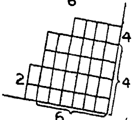
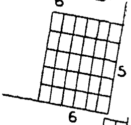
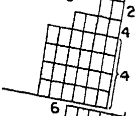
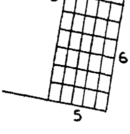
From these practical trials it appears that the above dimensions would be desirable for the general type of barrow in use, i e , the type with the axle 1 in or less from the front of the loading platform

Arrangement of Load—The value of the measurement of the palm-height of the worker as an index of the optimum arrangements of the load was tested and proved This measurement enables the works' foreman to inform a new worker of the most suitable arrangement of burnt or green bricks for him to adopt Some setters have by experience found that certain arrangements of green bricks suit them best Their palm-heights were measured and it was found that the arrangements recommended purely from consideration of palm-height were the ones which they had adopted

It was suggested to one setter of experience, whose palm-height measured 30 inches, that the arrangement of the load of 60 green bricks shewn in Table VI for his particular palm-height would be the best for him to adopt He at once stated that that was the arrangement he was using and had told the press boys to load up for him in that way

The works' foreman, when engaging new setters or drawers, could no doubt save them a great deal of unnecessary labour by measuring their palm-heights and informing them of the arrangement of bricks most suitable for their stature by reference to Table VI which shews the optimum arrangements of the loads of burnt and green bricks for men of various palm-heights

TABLE VI

	Arrangement.	Balance Height Inches	Suitable for men of Palm Height. Inches
Arrangements of loads for Drawers' Load, 70 Burnt bricks		36	34-35
		34½	32-34
		32	26-31
Arrangements of loads for Setters: Load, 60 Green bricks.		35½	34-35
		34¼	32-34
		32¾	29-31
		30¼	26-29

By adopting the optimum arrangement for his stature the worker is helped in two ways in particular, namely :—

(i) He is enabled to adopt a comfortable posture when wheeling; his circulation is helped thereby and fatigue lessened.

(ii) He saves himself from doing unnecessary work when raising and supporting the handles of the barrow

FURTHER OBSERVATIONS ON BARROW WORK.

(i) *Pace*—The normal brisk walking pace of the individual setter or drawer is the optimum rate of wheeling.

As a general rule the workers seem to adopt this pace, but certain workers tend to run with their barrows This is uneconomical from the point of view of the energy expended by the worker—he has no doubt to rest more often or unloads less rapidly in the kiln or truck.

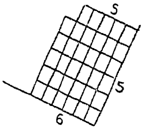
(ii) *Track.*—The importance of an uninterrupted run between presses and kiln and between kiln and rail siding should be noted One stop in a 50 yards' run means a 30 per cent. increase in the energy expended by the setter or drawer

Slowing down or stopping to turn at very sharp corners probably leads to unnecessary energy expenditure in some cases. No doubt some corners could be rounded off by arranging the steel plates in a curve instead of at right angles.

(iii) *Bearings.*—It is possible that considerable saving of energy expenditure could be made by the use of metal bearings for the wheel axles. When the present wooden bearings get worn, the friction is very much increased. The increased cost of metal bearings might be compensated for by their durability and the saving in labour on repairing the wooden ones quite apart from the saving to the individual setter or drawer.

(iv) *Arrangement.*—It would be a good thing if some of the shorter men among the drawers would give the following arrangement a fair trial.

Load 70 Burnt Bricks. Arrangement:



They may have already become very skilful at handling the usual arrangement, but the one suggested above is particularly suitable for men with palm-height of 29–31 in.

SUMMARY

The original report together with the report of the practical trials and the recommendations arising therefrom were left in the hands of the works' manager who undertook to put the suggestions to the test of routine works practice

The works' manager has since reported that:

(*a*) It has been proved that the length of 18 inches for the barrow legs is the best for the setters

(*b*) That the 18 inch barrow leg with ¼ inch iron shoe has been adopted the standard at the works.

(*c*) That the arrangements of the load based on measurement of the palm height of the workers are the most suitable for their use

(*d*) That the works' foreman will suggest the most suitable arrangement for any new setters or drawers in accordance with Table VI above

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Burnett I , and Pear, T. H (1925) . Motives in Acquiring Skill.—*Brit. J. Psych* , **16,** 2.

Cathcart, E. P., Bedale, E M., and McCallum, G. (1923) : Studies in Muscle Activity.—I. The Static Effect.—*J. Physiol.*, **57,** 3 & 4.

Cripps, L. D., Greenwood, M , and Newbold, E. M. (1923) : A Biometric Study of the Inter-relations of Vital Capacity, Stature Stem Length and Weight in a Sample of Healthy Male Adults.—*Biometrika*, **14,** 3 & 4.

Farmer, E. (1922) : Time and Motion Study.—*J. Ind. Hyg.*, **4,** 5.

Farmer, E. (1923) : Interpretation and Plotting of Output Curves.—*Brit. J. Psych.*, **13,** 3.

Farmer, E. (1927) : A Group Factor in Sensory Motor Tests.—*Brit. J. Psych.*, **17,** 4.

Farmer, E. (1927) : Parallelism in Curves of Motor Performance.—*Brit. J. Psych.*, **17,** 4.

Farmer, E. and Chambers, E. G. (1925): Concerning the Use of the Psycho-galvanic Reflex in Psychological' Experiments.—*Brit. J. Psych.*, **15,** 3.

Fraser, J. A. (1924): The Vocational Selection and Training of Operatives for the Weaving Industry.—*J. Nat. Inst. Ind. Psych.*, **2,** 2.

Fraser, J. A. (1926): Skill and Speed in Cotton Weaving.—*J. Nat. Inst. Ind. Pscyh.*, **3,** 3.

Fraser, J. A. (1927): The Value of Stoppage Analysis in the special reference to Weaving.—*J. Nat. Inst. Ind. Psych.*, **3,** 8.

Gaw, F. (1923): The Use of Performance Tests and Mechanical Tests in Vocational Guidance.—*J. Nat. Inst. Ind. Psych.*, **1,** 8.

Greenwood, M., and Newbold, E. M. (1923): On the Estimation of Metabolism from Determinations of Carbon Dioxide Production and on the Estimation of External Work from the Respiratory Metabolism.—*J. Hyg.*, **21,** 4.

Hambly, W. D., and McSwiney, B. A. (1922): The U-tube Manometer Test with relation to Muscular Exercise.—*Proc. Physiol. Soc.*, Oct 21, 1922

Hambly, W. D, Pembrey, M. S., and Warner, E. C. (1925): The Physical Fitness of Men assessed by various Methods.—*Guy's Hosp. Rep.*, Oct., 1925

Hewitt, E. M, and Bedale, E. M. (1923): A Study of the Comparative Physiological Costs of Different Methods of Weight Carrying by Women.—*Ann. Rep. of the Chief Inspector of Factories for* 1922.

Hill, A. V., Long, C. N. H., and Lupton, H. (1924): Muscular Exercise, Lactic Acid and the Supply and Utilisation of Oxygen.—*Proc. Roy. Soc.*, B. **96,** 438; **97,** 84; **97,** 155.

Hill, A. V., and Lupton, H. (1923): Muscular Exercise, Lactic Acid, and the Supply and Utilisation of Oxygen.—*Quart. J. Med.*, **16,** 62.

Hill, L., Vernon, H. M., and Hargood-Ash, D. (1922): The Kata-Thermometer as a Measure of Ventilation.—*Proc. Roy. Soc.*, B. **93,** 198.

James, H. E. O., and Thouless, R. H. (1926): A Note on the Effect of Polarisation in Psycho-Galvanic Experiments.—*Brit. J. Psych.*, **17,** 1.

Lupton, H. (1922): Relation between External Work and Time Occupied in a Single Muscular Contraction.—*J. Physiol.*, **57,** 1 & 2.

Lupton, H. (1923): Exercise and Oxygen.—*Med. School Gaz.*, **2,** 3.

Lupton, H. (1923): An Analysis of the Effects of Speed on the Mechanical Efficiency of Human Muscular Movement.—*J. Physiol.*, **57,** 6.

Muscio, B. (1920): Fluctuations in Mental Efficiency.—*Brit. J. Psych.*, **10,** 4.

Muscio, B. (1921): Is a Fatigue Test Possible?—*Brit. J. Psych.*, **12,** 1.

Muscio, B. (1921): Feeling Tone in Industry.—*Brit. J. Psych.*, **12,** 2.

Muscio, B. (1922): Motor Capacity with Special Reference to Vocational Guidance.—*Brit. J. Psych.*, **13,** 2.

Muscio, B., and Sowton, S. M. (1923): Vocational Tests and Typewriting—*Brit J. Psych.*, **13,** 4.

Newbold, E. M. (1923): Note on Dr. Burnside's Paper on Errors of Observation.—*Biometrika*, **15,** 3 & 4.

Pembrey, M. S., and Others (1922): Tests for Physical Fitness.—Part I.—*Guy's Hospital Reports*, Oct., 1921. Part II.—*Ibid.*, Oct., 1922.

Rusher, E. A (1922): The Statistics of Industrial Morbidity in Great Britain.—*J. Roy. Stat. Soc.*, **85,** 1.

Sargent, R. M. (1926): The Relation between Oxygen Requirement and Speed in Running.—*Proc. Roy. Soc. B.*, Vol. **100,** 1926.

Smith, May (1923): Practical Problems of Industrial Life.—*Ind. Welfare,* **5,** 58.

Smith, May (1923): The Laundry Trade.—*Laundry Record,* **33,** 388.

Smith, May (1926): Industrial Psychology.—*Article in Encyclopædia Britannica* (*XIIth Edition*).

Sturt, M. (1922): A Comparison of Speed with Accuracy in the Learning Process —*Brit. J. Psych.,* **12,** 3.

Vernon, H. M. (1921): The Influence of Atmospheric Conditions on Industrial Efficiency.—*J. State Med.,* **29,** 353.

Vernon, H. M. (1921): The Influence of Fatigue on Health and Longevity. —*J. Ind. Hyg.,* **3,** 3.

Vernon, H. M. (1922): Recent Investigation on Atmospheric Conditions in Industry.—*J. Ind. Hyg.,* **4,** 8.

Vernon, H. M. (1923): A Note on the Causes of Output Limitation.—*J. Nat. Inst. Ind. Psych.,* **1,** 5.

Vernon, H. M. (1923): Atmospheric Conditions in Potters' Shops and the Efficiency of Various Types of Drying Stoves.—*Trans. Ceramic Soc.,* 22, p. 70.

Vernon, H. M. (1923): The Causation of Industrial Accidents.—*J. Ind. Hyg.,* **5,** 1.

Vernon, H. M., and Bedford, T. (1924): The Influence of Short Time on Speed of Production.—*J. Nat. Inst. Ind. Psych.,* **2,** 155.

Vernon, H. M. (1925): Can Laboratory Experiments on Output throw Light on Problems of Industrial Fatigue ?—*Brit. J. Psych.,* **15,** 4.

Vernon, H. M. (1925): The Kata-Thermometer as an Indicator of Radiant Heat.—*J. Nat. Inst Ind. Psych.,* **2,** 198.

Vernon, H. M. (1925): The Work of the Tin-Plate Doubler.—*J. Nat. Inst. Ind. Psych.,* **2,** 373.

Vernon, H. M. (1926): Is Effective Temperature or Cooling Power the Better Index of Comfort ?—*J. Ind. Hyg.,* **8,** 392.

Vernon, H. M. and others (1926): Methods of Investigating Ventilation and its Effects.—*Med. Res Council Spec. Rep. Series No.* 100.

Vernon, M. D. (1926): On Certain Effects of Long Spells of Repetitive Work.—*Brit. J. Psych.,* **16,** 3.

Warner, E. C. and Hambly, W. D. (1925): An Investigation into the Physiological Basis of the U-tube Manometer Test.—*Guy's Hosp. Rep.,* July, 1925.

Wilson, D. R. (1921): Some Effects of Environment on Efficiency and Safety.—*J. Roy. San. Inst.,* **42,** 3.

Wilson, D. R. (1921): The Work of the Industrial Fatigue Research Board, and its Applications to Industry,—*J. Roy. Soc. Arts,* **70,** 3660

Wilson, D. R. (1923): On Some Recent Contributions to the Study of Industrial Fatigue.—*J. Roy. Stat. Soc.,* **86,** 4.

Wilson, D. R. (1923): International Co-operation in the Study of Industrial Psychology and Physiology.—*International Labour Office, Studies and Reports, Sec. F., No.* 9.

Wilson, D. R. (1924): Some Observations on Industrial Lighting.—*J. Ind. Hyg.,* **5,** 10.

Wilson, D. R. (1924): Man in Relation to Production.—*First World-Power Conference,* **412.**

Wyatt, S. (1925): The Effect of Atmospheric Conditions on Health and Efficiency (with special reference to the Cotton Industry) —*J. Ind. Hyg.,* **7,** 7.

Wyatt, S. (1927): An Experimental Study of a Repetitive Process.—*Brit. J. Psych.,* **17,** 3,

Wyatt, S. and Weston, H. C. (1920): A Fatigue Test under Industrial Conditions.—*Brit. J. Psych.,* **10,** 4.

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Report No. 51.

MEDICAL RESEARCH COUNCIL.

INDUSTRIAL
FATIGUE RESEARCH BOARD.

A Study of Absenteeism in a Group of Ten Collieries.

By H. M. VERNON, M.D., and T. BEDFORD, Ph.D.
(assisted by C. G. WARNER, B.Sc.)

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PREFACE.

An investigation was recently conducted for the Industrial Fatigue Research Board,* the results of which indicated, in conformity with expectation on physiological grounds, that both the working capacity and the accident rate of miners were affected by the atmospheric conditions in which they worked. With the concurrence of the Health Advisory Committee of the Mines Department and with a financial contribution from the Miners' Welfare Committee, this work has since been extended with the primary object of exploring further the effects of the physical environment of the miner

This second investigation, the results of which are embodied in the present report, is based mainly on the records of absenteeism relating to about 23,000 miners working at a group of ten collieries in the same district, covering periods of twenty-one months to six years. These data, after classification according to the presumed cause of absenteeism, have been examined with the object of measuring the relation of different kinds of absenteeism to various operative factors, and more particularly to depth of working and atmospheric conditions. The principal conclusions are given on page 54, and need not be here repeated, but the Board think it desirable to direct attention to the caution with which, as the authors themselves admit, these conclusions must be accepted. Caution is imposed both by the nature of the subject and by that of the methods applied.

The question of the causes of absenteeism is clearly one of great complexity, involving not only the more physiological factors with which the present report is mainly concerned, but also a number of social factors, such as the "degree of settlement" of the working population, the distance between home and colliery, and the availability of other work for women. In the present instance, the effects of these disturbing causes have been lessened by the fact that the group of collieries studied were in the same neighbourhood and apparently subject to the same social conditions, but the possibility of their affecting to some extent the conclusions reached as to the other causes studied must not be disregarded.

Then again, the investigation from its very nature is inevitably subject to the limitations imposed on all statistical experiences. Correlation between one variable and another, which was the principal test applied in the report, implies association but not causation, for although, for two variable factors standing in the relation of cause and effect, the statistical correlation between their measures must be significant (in the case of direct causation approximating to unity under most conditions), yet the converse proposition is not true, and it cannot be inferred merely from the

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* Vernon, H. M., Bedford, T., and Warner, C. G. (1927).—The Relation of Atmospheric Conditions to the Working Capacity and Accident Rate of Miners.—*I.F.R.B. Report No.* 39.

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fact that two variables are highly correlated, that one is the "cause" of the other; independent evidence is usually called for before this can be regarded as established.

Subject to these necessary limitations, the Board are of opinion that the results of the present inquiry are well worthy of the attention of the industry and of others interested, as disclosing various factors possibly influencing absenteeism which call for further study.

Finally, it is perhaps hardly necessary to point out that the investigation, having been confined to a limited number of collieries, the absolute figures relating to absenteeism given in the report must not be regarded as representative of the country as a whole.

The Board would acknowledge their indebtedness to the members of the Special Committee of Reference, containing representatives of the Mining Industry, for the critical consideration of the results of the inquiry, and to Sir Richard Redmayne, K.C.B., for many valuable suggestions received from him during the preparation of the report for publication.

July, 1928.

A STUDY OF ABSENTEEISM IN A GROUP OF TEN COLLIERIES.

BY

H. M VERNON, M D , and T BEDFORD, Ph D , Investigators
to the Board, assisted by C G WARNER, B Sc

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1. Introduction.

Absenteeism amongst coal miners, whether due to avoidable or to unavoidable causes, is an important economic factor in the industry. As was pointed out by the Coal Commission (1926), the average time lost by absenteeism in the whole of the coal fields of Great Britain amounted in 1924 to the equivalent of about four weeks per year, or 8·5 per cent. of the possible working time. In different districts it varied between the extremes of 11 days and 39 days per year. It has gradually fallen of recent years, but it still involves a serious loss of efficiency and especially so because of the irregularity of its incidence. It is nearly always greater on Mondays than on other weekdays, and the coal hewers are more prone to absenteeism than the haulage men and other underground men who are dependent on them, whilst the surface workers show the least absenteeism of all. The Coal Commissioners concluded that on an average over half the absenteeism is due to unavoidable causes, such as sickness and accidents, but the relative amounts of avoidable and unavoidable absenteeism appear to vary a great deal in different districts, so that it is important to estimate them as accurately as possible with a view to determining their causation. The problem of absenteeism is an extremely complex one, and the more exact our knowledge of it, the more chance is there of reducing absenteeism by the application of appropriate remedial measures.

The information to be described was obtained at a group of ten collieries, all of which were situated within ten miles of one another, and within a few miles of two large towns. In all of the collieries one or other of two seams (D and E) was being worked, whilst in two of the pits both were being worked. The D seam was 4 to 6 ft. in thickness, and the E seam, 3½ to 6 ft. Four other seams of similar thickness were worked to a much more limited extent, as can be gathered from Table I. Counting a seam separately for each colliery at which it was tested, the total number of seams or localities investigated came to 17. Three of the pits, namely, A (1), A (2) and B, and three of the seams (C, D and F), recorded in this Table were examined by us in the course of a previous investigation (1927), but only two pits were then referred to, as collieries A (1) and A (2) are connected underground, and were then referred to as "Colliery A."

It will be seen that the average depth of the various pits at the coal face varied from 616 to 2,269 ft., and the number of men employed varied from 428 to 3,036, the total coming to 18,455 (or 22,911, including the surface men). Pit A (1) is entered twice in the Table, as we were able to get separate absenteeism statistics for each of the two seams worked. At four other pits the statistics likewise relate to one seam only, but at the remaining five pits they relate to the combined data of two or three seams.

The average ages of the men in the various pits are given in the last column of the Table. It will be seen that they do not show any regular relationship to the depth of the pit.

TABLE I.—*The collieries and seams investigated.*

Collieries. (10)	Seams. (17)			Depth in feet at coal face.	No. of men underground. (18,455)	Average age in years of	
	D.	E.	Others			Coal face Workers	Other Underground Workers.
A (1) ..	—	—	C	616	624	40·8	30·0
N .	—	E	G, H	990	1,742	33·0	27·5
A (1) ..	D	—	—	1,359	428	41·8	32·2
Q ..	D	E	—	1,537	1,758	38·0	32·9
J ..	—	E	—	1,608	1,722	39·1	28·8
M ..	D	E	—	1,777	2,890	34·9	31·4
A (2) ..	D	—	—	1,778	537	39·2	31·2
P ..	—	E	—	1,850	1,831	34·1	28·8
K ..	D	—	F	1,886	2,263	31·5	27·9
B ..	D	—	F	1,969	1,624	37·9	26·2
L ..	—	E	—	2,269	3,036	39·5	32·5

Although our data relate to a body of nearly 23,000 men, it will be realised that these form only a small sample of the whole coal-mining industry. In addition, the investigation was confined to one locality in one coalfield. Because of these limiting factors it should be understood that our conclusions can only be regarded as provisional until they are tested and confirmed by investigation in other areas.

2. Absenteeism due to all Causes combined.

An accurate record of the weekly absenteeism is kept at each mine, such absenteeism indicating the number of shifts missed out of the total number possible. These records extend back for a number of years, but we thought it useless to go earlier than 1920, owing to the upsetting effect of war and post-war conditions. We obtained the weekly records of absenteeism for a 6⅓ year period (1920–26) at all the collieries enumerated in Table I, except J and M. As will be mentioned in the next section, we obtained another series of records lasting over a shorter period at these two collieries, but we thought it best not to mix them up with those under discussion.

We classified the men according as they were (*a*) workers at the coal face, including trammers, and (*b*) haulage men and others working underground. They were then split into four groups, according to the average depth of the workings. In order to determine if any seasonal variation of absenteeism existed, we averaged the results obtained in the four winter months (December to March), the four summer months (June to September), and the two two-month intermediate periods. These results are recorded in Table II, and are plotted in Fig. 1. It will be seen that the absenteeism varied to a marked extent with the depth of the workings, for the coal face men working at a depth of over 2,000 ft. lost 17·0 per cent. of working time, as compared with the 13·8 per cent. shown by those working at a depth of less than 1,000 ft.;

i.e., an excess of 23 per cent. Men working at intermediate depths showed an intermediate amount of absenteeism, though it was not in close proportion to the depth. The other underground workers showed less than two-thirds the absenteeism of the coal face workers, but the men working at over 2,000 ft. had 46 per cent. more absenteeism than those working at under 1,000 ft.

As can be gathered from the data on the right side of Table II, the variation of absenteeism with depth of workings was not due to any distinct differences in the ages of the men composing the different groups.

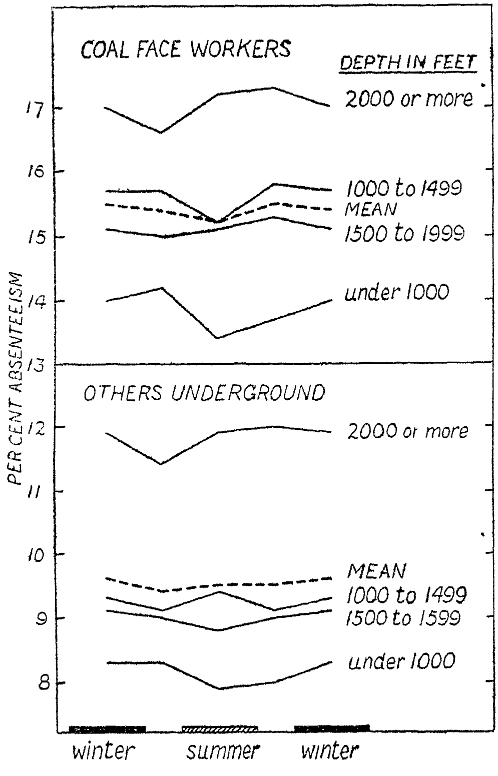

FIG. 1. Absenteeism in relation to depth of workings and to season.

TABLE II.—*Absenteeism in relation to depth and to season.*

No. of seams.	Range of depth.	Mean depth in feet.	Coal face workers.					Other underground workers.					Average age in years of	
			Dec – Mar.	Apr.– May.	June– Sept.	Oct.– Nov.	Mean.	Dec.– Mar.	Apr.– May.	June– Sept.	Oct.– Nov.	Mean.	Coal face men.	others underground
3	Under 1,000 ft.	651	14·0	14·2	13·4	13·7	13·8	8·3	8·3	7·9	8·0	8·1	34·3	28·5
3	1,000 to 1,499	1,335	15·7	15·7	15·2	15·8	15·6	9·3	9·1	9·4	9·1	9·2	38·5	30·5
5	1,500 to 1,999	1,848	15·1	15·0	15·1	15·3	15·1	9·1	9·0	8·8	9·0	9·0	36·1	29·4
3	2,000 and over	2,160	17·0	16·6	17·2	17·3	17·0	11·9	11·4	11·9	12·0	11·8	36·3	28·9
			15·5	15·4	15·2	15·5	15·4	9·6	9·4	9·5	9·5	9·5	—	—

The individual curves in Fig. 1 show that there was no consistent seasonal variation in the absenteeism, but the mean results for all depths show a slight diminution in the warmer months of the year.

The absenteeism observed by us is considerably greater than that recorded by the Coal Commission. Their statistics show that absenteeism for the whole of Great Britain averaged 8·5 per cent. the extremes ranging from 4·2 to 14·7 per cent. Their data include surface men, who have a better record than underground men, and if our own surface men data—which are described hereafter—are included with the rest, the mean absenteeism comes to 12·5 per cent. Hence it is desirable that, for comparison purposes, an investigation similar to ours should be made in a district showing an absenteeism rate lower than the average.

We shall see (§3(*a*)) that the considerable influence of depth of workings upon the total absenteeism of the coal face workers was due almost entirely to its affecting the time lost through sickness and accidents, but amongst the other underground workers atmospheric conditions appeared to exert a distinct influence on voluntary absenteeism as well as upon sickness and accidents.

3. Absenteeism due to Sickness.

Since August, 1924, the collieries investigated by us have made monthly returns of the time lost by sickness, accidents and other causes to a local association, and we were able to obtain access to most of these records at the individual collieries. The mere fact that a record of this sort is made does not prove that it is reliable, for sickness records are notoriously uncertain. In many industrial establishments the plea of sickness as a cause of absenteeism is accepted only if it is substantiated by a doctor's certificate, but even then it is not very reliable, as it may be difficult for a busy doctor to discover if the sickness is genuine, and some doctors grant certificates more readily than others. At the collieries where we worked, no demand for a doctor's certificate was made, and dependence was placed on the word of the individual miner, who had to account for any absence of more than one shift, coupled with the judgment of the timekeeper, who is usually a shrewd man with a considerable knowledge of personalities. As the result of careful inquiries, we concluded that the sickness data were reliable at seven of the ten collieries investigated, but the data obtained at the remaining three in respect of sickness were unreliable, though our information was reliable in respect of total absenteeism and of time lost through accidents. Owing to the advent of the prolonged coal dispute in May, 1926, we were able to obtain the data for a 21-month period only.

In order to ascertain more closely the association of sickness and other causes of absenteeism with temperature and other atmospheric conditions underground, we made a fairly extensive survey at each of the ten pits. Between October, 1925, and April, 1927, we made altogether 471 sets of observations, or at the rate of 47 per colliery. Of these observations, 280 were made at the coal face, 104 in the lesser haulage roads, 69 in the main haulage roads, and 18 at the pit bottom. Each set of observations consisted in the determination of the dry and wet bulb temperatures (by means of an Edney sling hygrometer), and of the dry and wet kata-thermometer cooling powers. From the dry kata cooling power the air velocity was calculated, but in some of the haulage roads, where the air had a velocity of several hundred feet a minute, the velocity was determined directly by means of a vane anemometer. The observations were distributed, so far as possible, in rough proportion to the numbers of men working at various places underground, except that the coal face observations, taken as a whole, were rather in excess of those made elsewhere. In some instances, where the observations were not distributed in sufficiently close relationship to the numbers of workers, the mean atmospheric conditions were calculated by weighting the observations so as to rectify the lack of proportion. In any case, owing to the wide variations in temperature and velocity which are found between the bottom of the downcast shaft and the coal face, it is very difficult to obtain a reliable figure for the average atmospheric conditions experienced by the underground men other than the coal face workers, though that for the coal face workers can be ascertained with fair accuracy.

The mean results are recorded in Table III. In the observations at colliery A (1), which are given separately for the C and the D seams, the total absenteeism recorded does not correspond exactly with the sum of the figures given for the individual causes of absence, as the sickness figures were unobtainable for five months out of the 21 investigated.

It will be seen that the atmospheric conditions observed at the coal face differed considerably from those observed elsewhere underground. Owing to the greater depth and to other factors, the temperature was usually about 5° F. higher, whilst the air velocity was much less. In consequence, the cooling power of the air at the coal face was a good deal lower.

In the lowest line of the Table is shown the average percentage of time lost from sickness and other causes at the seven pits where reliable data were obtained. The total absenteeism of the coal face workers and of the other underground workers was almost the same as that recorded in Table II, and of this total rather less than half was due to sickness and accidents. The various collieries are arranged in the Table according to their depth, and it appears that, on the whole, men working in the deeper pits suffered more sickness and accidents than those working in the shallower pits. In order to estimate the correlation between the two variables, we have treated each monthly percentage at a colliery as a separate item, though the temperature and other measurements were taken to be the same throughout. We thereby obtained from 155 to 228 pairs of observations from which to calculate the correlation coefficients.*

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* The validity of these coefficients is discussed in the Appendix.

TABLE III.—*Mean atmospheric conditions and absenteeism at various collieries.*

Colliery	Mean depth at coal face in feet	Coal face workers										Other underground workers									
		Temperature.		Cooling power.		Air velocity.	Percentage of absenteeism.				Men employed.	Temperature		Cooling power.		Air velocity	Percentage of absenteeism.				Men employed
		Dry bulb.	Wet bulb.	Dry.	Wet.		Sickness	Accidents	Voluntary.	Total		Dry bulb	Wet bulb.	Dry.	Wet		Sickness	Accidents	Voluntary	Total.	
		°	°									°	°								
A (1), C..	616	64·6	62·2	5·7	15·2	18	3·3	1·7	8·2	13·5	362	61·9	58·3	10·3	24·4	128	2·5	1·0	3·6	7·5	262
N ..	990	69·0	65·4	6·2	16·4	51	3·0	2·5	11·7	17·2	911	68·1	63·1	7·8	20·5	102	2·3	1·8	6·3	10·4	831
A (1), D..	1,359	77·3	71·6	3·4	11·3	20	5·5	4·5	8·9	18·8	228	72·3	65·8	7·7	21·8	158	4·3	1·4	3·2	8·8	200
Q ..	1,537	79·2	69·7	3·8	14·3	48	—	2·0	—	14·7	854	71·0	61·3	8·9	23·3	206	—	1·0	—	9·9	904
J ..	1,608	76·8	68·8	5·0	17·4	80	4·2	2·0	3·9	10·1	716	75·1	65·3	5·4	16·9	79	3·1	1·2	3·0	7·3	1,006
M ..	1,777	80·3	71·7	3·7	14·0	55	5·4	2·7	6·8	14·9	1,284	76·6	67·1	6·0	19·0	136	3·1	1·5	4·6	9·2	1,606
A (2) ..	1,778	81·4	76·2	2·7	10·2	21	3·9	2·2	7·0	13·1	251	72·4	62·7	8·3	23·8	196	3·3	1·2	2·8	7·3	286
P ..	1,850	77·9	72·7	7·4	22·2	276	—	1·6	—	19·4	1,049	72·6	65·4	8·5	22·4	211	—	1·7	—	14·0	782
K ..	1,886	80·1	74·5	3·1	11·8	26	3·4	2·5	11·3	17·2	1,305	73·2	65·3	7·5	20·1	163	3·1	1·8	6·0	10·9	958
B ..	1,969	83·6	75·0	2·7	11·6	41	—	3·2	—	18·8	774	79·8	68·7	4·7	16·8	111	—	1·3	—	8·4	848
L ..	2,269	82·2	74·0	3·5	13·7	71	6·1	3·3	12·5	21·9	1,217	77·1	68·1	7·6	21·2	264	5·0	2·2	8·8	16·0	1,819
Means of complete sets of data							4·3	2·7	8·8	15·8							3·3	1·5	4·8	9·7	

(a) *Temperature.*

The correlation of absenteeism with the air temperature is recorded in Table IV. It will be seen that there was a positive correlation coefficient of ·34 to ·51 between wet or dry bulb temperature and absenteeism from sickness, whilst that between temperature and absenteeism from accidents was smaller, and ranged from ·17 to ·31. The correlation of temperature with absenteeism from voluntary causes was practically *nil* in the coal face workers, but showed a moderate figure in other underground workers, while the correlation of temperature with total absenteeism was similar in both groups of workers.

TABLE IV.—*Correlation of absenteeism with temperature of air.*

Cause of absenteeism.	No. of observations	Coal face workers.		Other underground workers.	
		Dry bulb.	Wet bulb.	Dry bulb.	Wet bulb.
Sickness .. .	155	+·466 ± ·042	+·342 ± ·048	+ 473 ± 042	+·513 ± ·040
Accidents .	228	+ 240 ± 042	+·242 ± ·042	+·174 ± ·043	+ 308 ± 040
Voluntary causes	155	− 030 ± ·054	+ 062 ± ·054	+·225 ± ·051	+·393 ± 046
All causes.. ..	228	+·248 ± ·042	+ 307 ± 040	+ 213 ± ·043	+ 343 ± 039

In order to be able to appreciate fully the significance of the correlation coefficients, it is desirable to indicate the inter-relationships of the individual data on which they are based by means of regression diagrams. As the frequent introduction of such diagrams tends to break the continuity of the argument, they have been relegated to the Appendix.

Another method of demonstrating the relationship of sickness to underground temperature is to take the whole of the miners, irrespective of the pit in which they happened to be working, and group them according to the average temperature conditions experienced. It will be seen from Table V that 1,273 coal face men (who worked in two of the pits) experienced a mean dry bulb temperature of less than 70 deg., and they lost 3 per cent. of their shifts from sickness. There were no pits where the average temperature for the coal face men was 70 deg. to 74·9 deg., but those working at 75 deg. to 79·9 deg. suffered 50 per cent. more sickness than the low temperature workers, and the large group of men working at 80 deg. and upwards suffered 63 per cent. more. The other underground workers showed corresponding increments of sickness with rise of temperature, though they were working under somewhat cooler conditions. The sickness appeared to increase rather more rapidly with rise of wet bulb temperature than with rise of dry bulb, as can be gathered by comparing the curves in Fig. 2.

TABLE V.—*Absenteeism from sickness in relation to temperature.*

Range of temperature		Coal face workers			Other underground workers.		
		Mean temperature	No of men	Percentage of time lost	Mean temperature	No. of men	Percentage of time lost
		°			°		
Dry bulb	Under 70°	67·9	1,273	3·0	66·7	1,093	2·3
	70° to 74·9°	—	0	—	72·9	1,444	3·2
	75° to 79·9°	76·9	944	4·5	76·5	4,431	4·0
	80° or more..	80·9	2,773	4·9	—	0	—
Wet bulb	Under 62° ..	—	0	—	58·3	262	2·5
	62° to 65·9°	64·6	1,273	3·0	64·5	3,281	3·0
	66° to 69·9°	68·8	716	4·2	67·7	3,425	4·2
	70° to 73·9°	71·7	1,512	5·4	—	0	—
	74° or more..	74·4	2,773	4·7	—	0	—

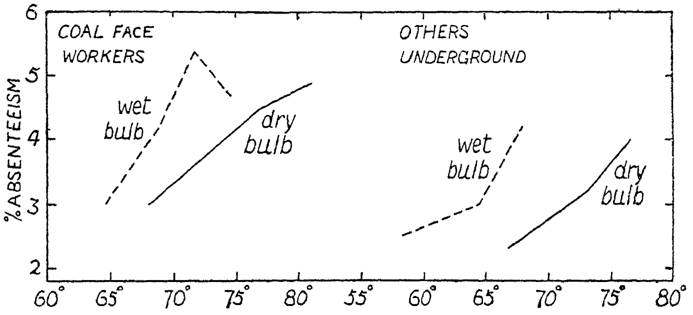

FIG. 2 Relationship of sickness to temperature at all collieries combined

Surprise may be felt at the very marked effect of underground temperatures on sickness, for many dwellers in warm climates habitually experience higher temperatures than those investigated by us, without ill effects. Presumably the causation of the sickness depends, not on the high temperatures at which the miners perform their work, but on the sudden changes experienced when coming to the surface. Sometimes the surface air temperature is 50 deg. lower than that underground, near the coal face, and an over-heated and freely perspiring man, on emergence into such cold air, would be very liable to catch a chill.

(b) *Cooling Power of Air.*

The correlation of sickness absenteeism with the dry and the wet kata cooling power of the air is recorded in Table VI. The coefficients were almost always negative in sign, for the absenteeism tended to increase as the cooling power of the air diminished. By comparing the coefficients with those recorded in Table IV, it will be seen that the correlation of sickness with cooling power was smaller than its correlation with temperature. The reason is that the cooling power depends on air movement as well as on temperature, and as is indicated below, increased air movement appears to increase sickness rather than diminish it. Hence a given reduction of cooling power would tend to increase sickness, in so far as the reduction was due to an increase of temperature, but would tend to decrease sickness, in so far as it was due to increase of air movement.

TABLE VI.—*Correlation of absenteeism with cooling power of air.*

Cause of absenteeism	No of observations	Coal face workers		Other underground workers.	
		Dry kata cooling power	Wet kata cooling power	Dry kata cooling power.	Wet kata cooling power.
Sickness	155	− ·371 ± ·047	− 156 ± ·053	− 109 ± 054	+ 020 ± ·054
Accidents	228	− 398 ± 038	− 424 ± ·037	− 070 ± 044	− 101 ± ·044
Voluntary causes	155	− 007 ± ·054	− 155 ± 053	+ 015 ± 054	− 078 ± 054
All causes	228	− 029 ± ·045	− 007 ± ·045	+ 117 ± 044	+ 085 ± 044

Our previous investigation on the working capacity of coal miners (1927) showed that the wet kata cooling power was a better index of the suitability of atmospheric conditions for work than the dry kata cooling power, but the present observations show that sickness is correlated more closely with dry kata cooling power than with wet. Perhaps this may be due to the disturbing influence of the air velocity factor. The same factor may be responsible for the lack of correlation between cooling power and total absenteeism.

The coefficients recorded on the right side of Table VI show that there was no definite relationship between the absenteeism of other underground workers and the cooling power of the air.

(c) *Air Velocity.*

The correlation of absenteeism with air velocity is recorded in Table VII. It will be seen that for "other underground workers" the coefficient between sickness and air velocity attained the high positive value of ·59, whilst for coal face workers it was only ·28. The correlation of absenteeism from voluntary causes with velocity was likewise rather high in "other underground workers," but the significance of this coefficient is doubtful, owing to the possible inclusion of some absenteeism due to sickness. It will be noted that whilst the other underground workers showed a positive correlation between absenteeism from accidents and air velocity, the coal face workers showed a substantial negative correlation. This discrepancy, which is referred to again later on, probably depends on the fact that the air velocities experienced by the coal face workers were much lower than those to which the other miners were subjected.

TABLE VII.—*Correlation of absenteeism with air velocity.*

Cause of absenteeism.	No. of observations	Coal face workers	Other underground workers
Sickness	155	+·278 ± ·050	+·586 ± ·036
Accidents	228	−·293 ± ·041	+·207 ± ·043
Voluntary causes	155	−·092 ± ·054	+·453 ± ·043
All causes	228	+·230 ± ·042	+·610 ± ·028

TABLE VIII.—*Absenteeism from sickness in relation to air velocity.*

Coal face workers.					Other underground workers.				
Range of air velocity (ft. per min)	Mean velocity	No of men	Mean age in years	Per-centage of time lost	Range of air velocity (ft per min)	Mean velocity	No of men.	Mean age in years	Per-centage of time lost.
Under 30	24	2,146	34·6	3·7	Under 120	90	1,837	28·2	2·7
30 to 59 .	53	2,195	34·1	4·3	120 to 159	137	2,068	31·3	3·1
60 or more	74	1,933	39·4	5·5	160 to 199	171	1,244	28·7	3·1
					200 or more	264	1,819	32·5	5·0

On classifying the sickness data obtained at the various collieries according to the air velocity, the mean results recorded in Table VIII were obtained. They are plotted in Fig. 3, and it will be seen that as the air velocity increased, the sickness showed a slow rise at first, followed by a more rapid one. Thus, in the "other underground workers" an increase of velocity from 90 ft. to 171 ft. per minute was associated with a rise of only 15 per cent in sickness, whilst the further increase of velocity to 264 ft. was associated with an additional rise of 70 per cent.

The marked rise of sickness observed in coal face workers at velocities of 60 ft. or more is probably due in part to the fact that the men in this group were 5 years older than those in the other groups. (*Cf.* Table VIII.)

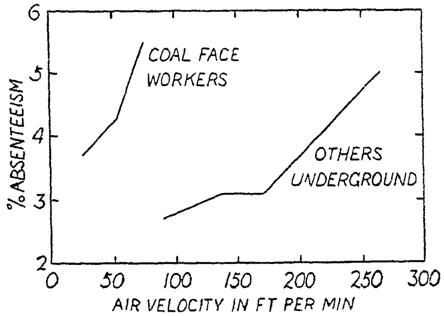

FIG. 3 Relationship of sickness to air velocity at all collieries combined.

The air velocities recorded in Table III, and the other velocities subsequently recorded in Tables XI and XII, are the means of individual values possessing a fair degree of divergence. The range and frequency of the velocities observed at collieries A (i.e., A (1) and A (2) combined) and B have been already recorded by us (1927), and as those observed at other collieries were similar, it seemed unnecessary to record them in addition. It should be stated that of the coal face observations made at the collieries other than A and B, nine-tenths were at long wall faces, and only one-tenth at headings and pillars.

The seemingly adverse effect of the comparatively small increments of air velocity on the sickness of coal face workers might be thought to contradict every-day experience obtained in factories and other buildings above ground. As the result of numerous observations made in ten factories (1926), we found that in summer time, at a temperature of 75 deg., the air velocity in the workrooms averaged 51 ft. per minute, and we recommended that when possible it should be increased to 100 ft. In the present observations, made at a mean temperature of 76·5 deg. (dry bulb), the air velocity in the various pits ranged from 18 ft. to 80 ft., and averaged 43 ft As the miners were engaged in severe physical work, it might be thought that they would need a much higher air velocity than the above-mentioned factory operatives, whose work was for the most part of a light character. Doubtless a higher air velocity would have been better for the physical efficiency of the men, but it may induce sickness from chills We showed (Reports 39 and 41, 1927) that coal face men are frequently held up by lack of tubs and from other causes, these involuntary rests sometimes lasting over 20 minutes. It is evident that a miner, streaming with perspiration and wearing nothing but breeches, would under such circumstances be very sensitive to air currents, unless he took the precaution of temporarily donning some extra clothes.

Having regard to the possible effect of age of the men on the result observed, and of other unknown factors such as the presence of impurities in the air of the mines, it is better to suspend judgment about the effects of air velocity on sickness until further information is obtained.

(d) *Age of Men.*

It is well known that sickness tends to increase with increase of age, and the sickness absenteeism of the miners conformed to the general rule Our data were not altogether satisfactory, as we were unable to obtain information about the sickness of individual men of known age, but only about the average sickness of all the underground men at each colliery after separation into the two groups of face workers and others. We obtained the frequency distributions of the ages of all the men who signed on after the coal disputes of 1921 and 1926, and from these figures, which agreed well with one another, we calculated the average ages during the 1924–26 period for which the absenteeism data were available. The average ages of the coal face workers varied a good deal at the different collieries, the extremes ranging from 31·5 to 41·8 years ; but those of the other underground men were more steady, and ranged only from 27·2 to 32·9 years. On correlating the monthly absenteeism data with the average ages of the men at the eight pits, we found that the coal face workers gave a coefficient of +·328 ± ·048 in respect of sickness absenteeism, and the other underground workers, one of +·569 ± ·037. The other coefficients were small and irregular, so they are not worth quoting.

On classifying the men according as the average age at a colliery fell in one or other of three groups, the following results were obtained:

TABLE IX.—*Absenteeism from sickness in relation to average age of men at the collieries.*

Average age of men at colliery	Coal face workers			Other underground workers		
	Mean age	No of men.	Percentage of time lost	Mean age	No of men	Percentage of time lost.
Under 28 years . .	—	—	—	27·7	1,789	2·7
28 to 31·9 years . .	31·5	1,305	3·5	30·4	3,160	3·1
32 to 35·9 years . .	34·1	2,195	4·3	32·5	2,019	5·0
36 or more	39·7	2,774	5·1	—	—	—

(e) *Sickness in Relation to Season.*

In order to determine if there were any seasonal variation in the absenteeism from sickness, we classified the sickness data obtained at the eight pits on the same plan as that described above for the total absenteeism data. The results showed that in every pit the sickness was least during the summer months (June to September), both for the coal face workers and for the others; but the incidence of the maximum sickness was irregular, for it came in October to November as frequently as in winter (December to March), and sometimes fell in April to May.

A better way of testing the seasonal variation was to classify the data according to the temperature and irrespective of the pit. On comparing the sickness experienced in the four winter months and the four summer months, the results plotted in Fig. 4 were obtained. It will be seen that though the sickness increased fairly steadily with the dry bulb temperature, it was always, with one slight exception, rather greater in winter than in summer.

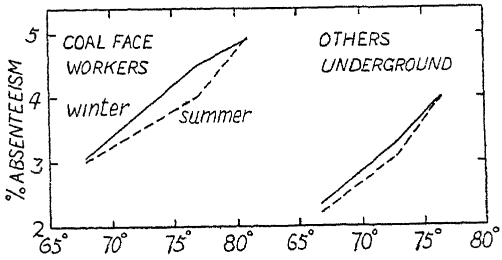

FIG. 4. Sickness in relation to season and to temperature.

The sickness data hitherto described did not distinguish the various causes of sickness, but we were able to obtain some information on this subject from an entirely different source. At the request of the Mines Department, the Medical Research

Council instituted a preliminary enquiry into the causes of sickness in coal miners, and the results obtained were placed at our disposal. Details concerning the sickness of 3,208 coal face workers in the year 1922 were obtained from the National Health Insurance cards kept by a large Friendly Society in Scotland. They related to the men in 17 pits, situated for the most part in Fifeshire, Lanarkshire and Ayrshire. Only a portion of the men in these pits belonged to the Friendly Society in question, and as the coal face workers form only about half of all the underground men, the average number of men investigated amounted only to 30 per cent. of the total underground workers in the 17 pits. Nevertheless, it is probable that they were a fair sample of the whole.

We classified the sickness under several headings, but owing to the small mass of data available, we decided to reduce them to two, consisting of (*a*) sickness due to respiratory diseases (bronchitis, pneumonia, pleurisy, pharyngitis, pleurodynia, asthma), and to influenza ; (*b*) sickness due to all other causes (accidents excluded). The reason why we grouped influenza with respiratory diseases was because of doubts about diagnosis. For instance, at one pit scarcely any sickness was attributed to respiratory diseases, whilst that assigned to " influenza " was extremely large. At an adjoining pit nearly equal amounts of sickness were assigned to the two causes. Such a marked difference could scarcely have been genuine.

In order to determine if the sickness was dependent on temperature, we separated the pits into three nearly equal groups, according to their depth. We made no direct observations of temperature in the workings, but the Mines Department supplied us with information about the average depth of the workings at each pit, and as we shall see hereafter, temperature is very closely correlated with depth, the coefficient observed by us being +·952 ± ·015. We also divided the sickness records according as they occurred in the six winter months (November to April), or the six summer months. The 53 men on disablement benefit (which is incurred after the receipt of 26 weeks' full pay) were excluded altogether from our analysis, as the inclusion of chronic cases may lead to erroneous conclusions when the volume of data is inconsiderable. Hence the recorded data relate to 3,155 men, and not the 3,208 men above mentioned.

TABLE X.—*Effect of depth of pit and of season on sickness.*

	Mean depth in feet	No of men	Days lost from respiratory illness in			Days lost from all causes.		
			Winter.	Summer.	Percentage excess in winter.	Winter.	Summer.	Percentage excess in winter.
8 shallow pits .. .	881	999	2·24	0·72	211	4·8	3·3	45
4 medium pits .. .	1,412	988	2·83	1·19	138	5·5	4·2	31
5 deep pits .. .	1,970	1,168	1·83	0·80	129	4·0	2·7	48
	—	—	2·30	0·90	159	4·8	3·4	41

The mean results recorded in Table X show the number of working days lost from sickness in each six-month period, the initial three days' sickness—for which benefit is not paid—being included. It will be seen that the sickness from all causes was considerably greater in the winter than in the summer, the average excess amounting to 41 per cent. It seemed to be due entirely to the additional respiratory illness experienced in the winter, for this averaged 1·4 days more than in the summer, or exactly the same amount as that by which the winter sickness from all causes exceeded the summer sickness. The total sickness per year, namely, 8·2 days, was 3·1 per cent. of the possible shifts which could be worked, if we accept the shift figure given by the Coal Commission for the whole of Scotland in 1924. Hence it was slightly greater than the average time observed by us, which amounted to 2·7 per cent.

The present results differ from those previously described in showing no increase of sickness with increasing depth of pit; i.e., with increasing temperature. Judging from our own results, the dry bulb temperature of the air in the shallow pits was probably about 67 deg, and in the deep ones about 84 deg. The rather smaller rise of temperature than this which was recorded in the previous results (Table V), was accompanied by an increase in sickness of 63 per cent.

Another unexpected result relates to the respiratory illness. We see that in winter time the men working in shallow pits suffered three times as much illness of this character as they did in summer time, whilst the men working in deep pits suffered only twice as much. One would have expected that men working at a temperature of 84 deg. would get more overheated than those working at 67 deg., and would consequently be more liable to catch a chill when they came to the surface.

Evidently it is necessary to obtain more extensive information about sickness before definite conclusions can be arrived at. Our own data are more reliable than these Scottish data, as they relate to a larger group of men and they were obtained for a longer period. Moreover, they relate to the whole of the men working in a small number of somewhat similar pits in the same district, instead of a portion of the men working in a wide area, with very different types of pit, and very different atmospheric conditions above ground.

4. Absenteeism due to Accidents.

Accurate information concerning absenteeism from accidents is obtainable from the records of compensation cases. Previous to 1924 compensation was paid on all accidents involving an absence from work of over seven days, whilst from 1924 onwards the minimum time was reduced to an absence of over three days. We classified separately the accident records for the years 1924 and 1925 of all the ten collieries and 17 seams previously referred to. We calculated the accident frequency rate per 100,000 man-shifts worked, and the accident severity rate in terms of days lost per 1,000 hours worked. A shift, inclusive of the winding times, was assumed to be of 7½ hours' duration. In calculating severity rates, it is sometimes assumed that a fatal accident corresponds to the loss of 20 years of working life, or of 6,000 days of working time. Their inclusion on this basis causes the severity rates to be extremely irregular, for fatal accidents occurred, in our experience, at the rate of about two per pit per year, but in some cases there were none at all, and in others as many as six. Hence we found it best to calculate severity rates on the system previously adopted by us (1927), and assume that no accident, fatal or otherwise, caused a loss of more than 150 days (six months) of working time.

In order to determine whether there was a substantial relationship between accident frequency and the natural conditions at the coal face, we arranged the seams of the various collieries in order according to their degree of danger from falls of roof and side. In making this ranking, we chiefly relied on the opinion of the managers and others who had an intimate knowledge of the various collieries. We also arranged the seams in order according to their accident rate (see below), and obtained the following correlation coefficients between rankings of accidents and of natural conditions :—

Accident frequency from falls of ground, with natural conditions .. .. $r = + \cdot 18 \pm \cdot 16$
Accident severity from falls of ground, with natural conditions .. .. $r = + \cdot 22 \pm \cdot 16$

These coefficients suggest that there is a slight tendency to increase of accidents with increasing danger of natural conditions, but they are statistically insignificant. It is, of course, well known that a bad roof is very often easily controlled, and scrupulous care is taken to see that it is properly supported. Under a good roof men are very liable to take liberties. It has been pointed out by the Safety in Mines Research Board (Paper No. 6, 1926) that indifference to the timbering of good roofs is responsible for many accidents that could be prevented, with the result that good roofs prove to be as dangerous as bad roofs, if not more so.

(a) *Atmospheric Conditions.*

The accident frequency rate and severity rate of the coal face workers in 1924 and 1925 at each of the 17 seams are recorded in Table XI, together with the average atmospheric conditions experienced. The data are arranged according to the mean depth of the workings, and it will be seen that, on the whole, the accident rates tended to increase with depth. In Table XII the corresponding data for the other underground workers are similarly recorded, with the exception that the figures for the D and E seams at pit Q are given in combination instead of separately. It will be seen that the accident rates are considerably smaller than those observed in the coal face workers.

TABLE XI.—*Accident rates of coal face workers.*

Colliery and seam	Mean depth at coal face (ft).	Mean atmospheric conditions					Accident frequency					Accident severity					No of men employed
		Temperature.		Cooling power		Air velocity in feet per min	Falls of ground	Other causes	All causes			Falls of ground	Other causes	All causes			
		Dry bulb	Wet bulb	Dry	Wet				1924	1925	Mean			1924.	1925	Mean	
		°	°														
N, H ..	546	61·5	60·0	7·1	16·4	31	28	75	99	108	103	1·2	2·6	4·7	2·9	3·8	170
A (1), C ..	616	64·6	62·2	5·7	15·2	18	25	38	52	74	63	1·5	2·0	2·6	4·5	3·5	370
N, G ..	791	65·6	62·3	7·1	18·5	54	41	42	97	69	83	1·7	1·6	3·9	2·6	3·3	340
Q, E ..	1,260	75·9	69·5	4·7	16·4	56	48	49	93	101	97	1·8	1·4	2·9	3·5	3·2	479
A (1), D ..	1,359	77·3	71·6	3·4	11·3	20	50	47	73	122	97	3·0	1·9	4·3	5·5	4·9	234
N, E ..	1,386	75·8	70·9	5·0	14·7	68	52	59	115	107	111	2·3	1·5	4·1	3·5	3·8	381
M, E ..	1,420	78·1	71·2	3·7	12·8	34	39	57	85	107	96	1·2	1·6	2·9	2·6	2·8	391
J, E ..	1,608	76·8	68·8	5·0	17·4	80	61	67	130	126	128	2·0	2·1	4·0	4·3	4·1	691
K, D ..	1,715	78·7	74·4	3·3	10·8	24	50	102	158	146	152	1·7	2·6	4·5	4·1	4·3	587
A (2), D ..	1,778	81·4	76·2	2·7	10·2	21	46	45	80	101	91	2·0	2·1	3·8	4·5	4·1	245
P, E ..	1,850	77·9	72·7	7·4	22·2	276	33	39	75	69	72	1·3	1·1	2·7	2·1	2·4	1,036
Q, D ..	1,920	83·8	69·9	2·5	11·4	33	34	45	74	84	79	1·0	1·4	2·2	2·5	2·4	380
M, D ..	1,930	81·3	71·9	3·7	14·5	70	93	66	168	151	159	2·3	1·5	4·1	3·5	3·8	910
B, D ..	1,942	83·4	74·8	2·6	11·1	33	66	73	141	137	139	2·9	2·3	4·5	6·0	5·2	423
K, F ..	2,042	81·3	74·6	3·0	12·8	33	45	74	116	121	119	1·5	1·8	2·9	3·7	3·3	654
B, F ..	2,168	85·4	75·7	2·6	12·5	59	72	59	134	127	131	2·5	2·0	4·6	4·4	4·5	274
L, E ..	2,269	82·2	74·0	3·5	13·7	71	79	82	153	169	161	2·6	2·4	4·9	5·1	5·0	1,212

TABLE XII.—*Accident rates of other underground workers.*

Colliery and seam.	Mean atmospheric conditions.					Accident frequency					Accident severity					No of men employed
	Temperature		Cooling power		Air velocity in feet per min	Falls of ground.	Other causes	All causes			Falls of ground	Other causes	All causes			
	Dry bulb	Wet bulb	Dry	Wet				1924	1925.	Mean			1924.	1925	Mean	
N, H	59°·4	56°·0	9·2	22·3	69	7	35	45	39	42	0 3	1·4	1·4	2·0	1 7	111
A (1), C ..	61 9	58·3	10·3	24·4	128	4	33	44	31	37	0·1	1·5	2 0	1 3	1·6	260
N, G	64·6	60·1	8·5	21·4	90	13	36	57	41	49	0 6	1·5	2·4	1·7	2·1	273
Q, D + E ..	71·0	61·3	8·9	23·3	206	10	40	52	49	50	0·3	1·4	1·6	1·8	1 7	918
A (1), D ..	72 3	65·8	7·7	21·8	158	8	30	46	30	38	0·5	1 2	1·6	1·8	1·7	215
N, E	72 4	66·6	7·1	19·5	126	10	51	66	56	61	0 6	1·7	2·2	2·3	2·3	447
M, E	75·0	66 0	5·8	17 9	97	12	38	54	47	50	0·4	1·4	1·7	1·9	1 8	611
J, E	75·1	65·3	5·4	16·9	79	12	39	47	56	51	0·3	1·4	1·6	1·9	1·7	985
K, D	73·0	64 6	6·7	18·7	115	12	64	88	64	76	0·4	2·1	3 0	2·1	2 5	567
A (2), D ..	72·4	62·7	8·3	23·8	196	5	38	44	43	43	0·1	1·7	1·7	1 9	1·8	280
P, E	72·6	65·4	8·5	22·4	211	10	43	51	54	53	0·6	1·6	2 1	2 3	2·2	801
M, D	77 6	67·7	6 2	19·6	170	21	58	79	79	79	0·8	1·6	2·3	2·4	2 4	993
B, D	80·0	68·6	4 4	15·8	94	9	55	68	60	64	0·2	1·7	1·8	2·1	1·9	531
K, F	73·5	66·2	8·5	22·0	230	21	83	114	95	104	0·6	2·8	3·8	3·0	3·4	457
B, F	81·9	69·6	4·6	18·2	148	20	78	95	100	98	0·6	2·3	2·9	2·9	2·9	196
L, E	77·1	68·1	7·6	21·2	264	31	59	96	83	90	1 0	1·7	2·8	2·5	2·7	1,793

For the calculation of the correlations of accidents with atmospheric conditions the two yearly accident rates for each seam were regarded as separate observations, so there were 34 observations of frequency and of severity for the coal face workers, and 32 for the other underground men. The coefficients are recorded in Table XIII. It will be seen that the correlation of accident frequency with dry bulb and wet bulb temperatures was fairly high for coal face workers, and quite high for other underground workers. The accident severity rates show lower coefficients than the frequency rates, for a reason mentioned further on. The correlation of accidents with dry and wet kata cooling powers is, on the whole, lower than the correlation with temperatures because of the disturbing effect of the air velocity factor. Air velocity appears—for a reason previously mentioned and referred to again below—to have very little influence on accidents to coal face workers, though it showed a considerable positive correlation with accidents to other underground workers. In their case, therefore, an increase of accidents was associated with a rise of air velocity and also with a rise of air temperature ; but as these rises act in opposite directions on the kata-thermometer, one increasing its rate of cooling and the other diminishing it, it follows that the correlation of accidents with cooling power was small.

TABLE XIII.—*Correlation of accident rates with atmospheric conditions.*

	Coal face workers		Other underground workers.	
	Frequency	Severity	Frequency.	Severity.
Dry bulb temperature	+ 452 ± 092	+ 214 ± ·110	+·593 ± ·077	+·401 ± ·100
Wet bulb temperature	+ 461 ± ·091	+ 299 ± ·105	+ 623 ± 073	+·478 ± ·092
Dry kata cooling power	− 436 ± 094	−·357 ± ·101	− 381 ± 102	−·172 ± ·116
Wet kata cooling power	−·321 ± ·104	−·398 ± 097	− 312 ± ·108	−·125 ± 117
Air velocity	−·147 ± 113	− 299 ± ·105	+·418 ± 098	+ 431 ± ·097

The reason why the accident rates of coal face workers showed a small negative correlation coefficient with air velocity instead of the fairly substantial positive coefficient shown by other underground workers was entirely due to the very abnormal air velocity observed at one colliery (P). Here the velocity at the coal face was 276 ft. per min., and was greater than that observed in the airways, whilst no velocity higher than 80 ft. per min. was observed at any of the other seams. If this value is ignored, and the remaining accident rates are classified in four groups according to the air velocity, the mean results shown in Table XIV are obtained.

It will be seen that whilst the accident frequency was practically constant at all velocities under 60 ft. per min., it showed a considerable increase at a mean velocity of 72 ft. The accident severity was high at very low velocities, but fell to a minimum at one of 30 to 59 ft. per min. Then it rose rapidly like the accident frequency. There can be no doubt that a certain amount of air movement is necessary for the attainment of maximum working capacity, and presumably the same condition holds for the attainment of minimum accident liability. Arguing from the small amount of evidence here adduced, it seems probable that accidents reach their minimum when the air currents have a comparatively low velocity, such as 30 to 60 ft. per min. As has already been suggested in connection with the causation of sickness, their increase at higher velocities may be due to the men tending to get rather chilled when they are temporarily resting from work. They would, in consequence, become stiffer and clumsier in their movements.

It will be noted that the highest velocity group were at the greatest depth, and this fact may in part account for the higher accident rates then observed.

TABLE XIV.—*Accident rates in relation to air velocity.*

Range of air velocity.		Mean velocity	Mean accident frequency.	Mean accident severity.	Mean depth in feet.
Coal face workers	Under 30 ft per min.	21	101	4·22	1367
	30 to 39 ft. per min.	33	107	3·41	1574
	40 to 59 ft. per min.	56	104	3·65	1406
	60 to 80 ft. per min.	72	140	4·19	1809

All other conditions being equal, we might expect that the thinner the seam the greater would be the air velocity, and the increase of accidents associated with high velocities might therefore be attributable to the thinness of the seams. As a matter of fact, the results recorded later on show that the reverse relationship holds between thinness of seam and accident rate. In any case, the present observations indicate that there is no consistent relationship between thickness of seam and air velocity, as can be gathered from Table XV.

Table XV.—*Air velocity in relation to thickness of seam.*

Range of thickness of seam, in inches.	Mean thickness in inches.	Number of seams.	Mean air velocity in feet per min.
72	72	2	57
66 to 63	65	5	48
60	60	3	28
54	54	3	38
50 to 48	49	2	51
47 or less	40	2	165

TABLE XVI.—*Correlations of accident rates from various causes with atmospheric conditions.*

Atmospheric conditions.		Accident frequency.			Accident severity		
		Falls of ground.	Other causes	All causes.	Falls of ground	Other causes	All causes
Coal face workers	Dry bulb temperature	+·569±·078	+·188±·112	+·452±·092	+·323±·104	−·097±·115	+ 214±·110
	Wet bulb temperature	+·515±·085	+·257±·108	+ 461±·091	+·378± 099	−·007±·116	+·299± 105
	Dry kata cooling power ..	−·454±·092	−·275±·107	−·436±·094	−·332±·103	−·177±·112	−·357±·101
	Wet kata cooling power ..	−·227±·110	−·308±·105	−·321±·104	−·274±·107	−·362±·101	−·398±·097
	Air velocity	+·013± 116	+·067±·115	−·147±·113	−·116±·114	−·421±·095	−·299±·105
Other underground workers	Dry bulb temperature	+·491±·091	+·563± 081	+·593±·077	+·340±·105	+·308±·108	+·401± 100
	Wet bulb temperature	+ 537±·085	+·583± 079	+ 623±·073	+·466±·093	+·332±·106	+·478±·092
	Dry kata cooling power ..	−·277±·110	−·387± 101	−·381±·102	−·136±·117	−·138±·117	−·172±·116
	Wet kata cooling power ..	−·214±·114	− 317±·107	− 312±·108	−·101±·118	−·101±·118	−·125±·117
	Air velocity	+·470±·093	+·341±·105	+·418±·098	+·432±·097	+·292±·109	+·431±·097

Our results suggest that atmospheric conditions influence different types of accident to different degrees, and in order to obtain further light on the subject, we classified all our data separately under two headings : (*a*) accidents due to falls of roof, coal and side, and (*b*) accidents due to all other causes combined. Such accidents consist largely of strains incurred when lifting tubs, rails, etc. ; the crushing of fingers or arms between tubs and props ; the trapping of fingers between haulage ropes and pulleys ; the cutting of fingers against the iron on the edge of the tubs, or on loose strands of haulage rope ; injuries from picks and other tools, and from kicks of ponies.

As can be seen from Table XI, the accidents incurred by coal face workers from these two causes—for the years 1924 and 1925 combined—were, on the whole, nearly equal in number, though they varied a great deal in different pits. From Table XII it will be seen that the other underground men differed greatly from the coal face men as they incurred only about a fourth as many accidents from falls of ground as from other causes.

The correlation coefficients of accident rates from the two specified causes with atmospheric conditions are recorded in Table XVI. It will be seen that amongst coal face workers the correlations of accidents due to falls of ground were, on the whole, considerably greater than the correlations of accidents due to other causes. The correlation with dry bulb and with wet bulb temperature was particularly high : but amongst the other underground men the accidents due to falls of ground showed a lower correlation—in respect of frequency—than the accidents due to other causes, though a slightly higher one in respect of severity.

It is not worth while to give further details of the relationships between accidents to coal face workers and atmospheric conditions, because of the more satisfactory information adduced further on, but some of the details may be given for the other underground workers. When the data were grouped according to air velocity, the results recorded in Table XVII and plotted in Fig. 5 were obtained. It will be seen that the association between accidents

TABLE XVII.—*Accident rates of other underground workers in relation to air velocity.*

Range of velocity.	Mean velocity	Accident frequency.			Accident severity.			Total shifts worked
		Falls of ground.	Other causes.	All causes.	Falls of ground	Other causes.	All causes.	
Under 100 ft. per min...	87	11	42	53	0·35	1·49	1·84	1,233,694
100 to 149 ft per min.	125	11	56	67	0·44	1·89	2·33	780,872
150 to 199 ft per min...	174	16	49	65	0·62	1·51	2·13	734,507
200 to 249 ft per min...	213	12	51	63	0·51	1·77	2·28	1,064,427
250 ft. or more ..	264	31	58	89	0·94	1·71	2·65	852,443

from falls of ground and velocity was considerable, for the accidents were nearly three times more frequent at the highest velocities than at the lowest velocities, whilst the severity rate varied in similar proportion. Accidents from other causes were, however, comparatively little affected.

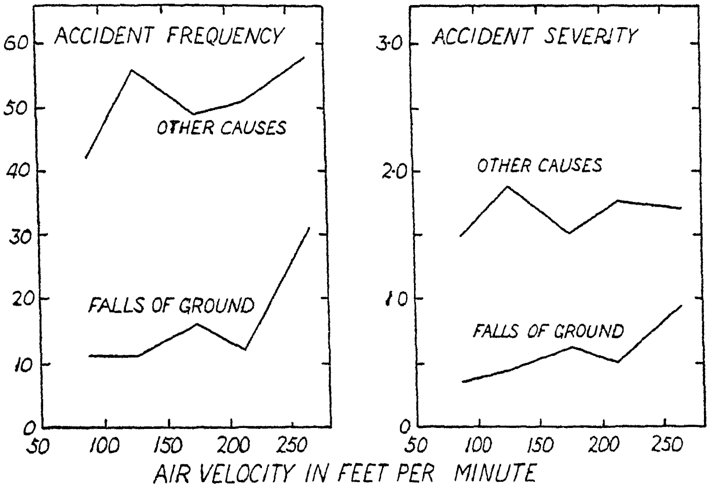

Fig 5 Accidents to other underground workers in relation to air velocity.

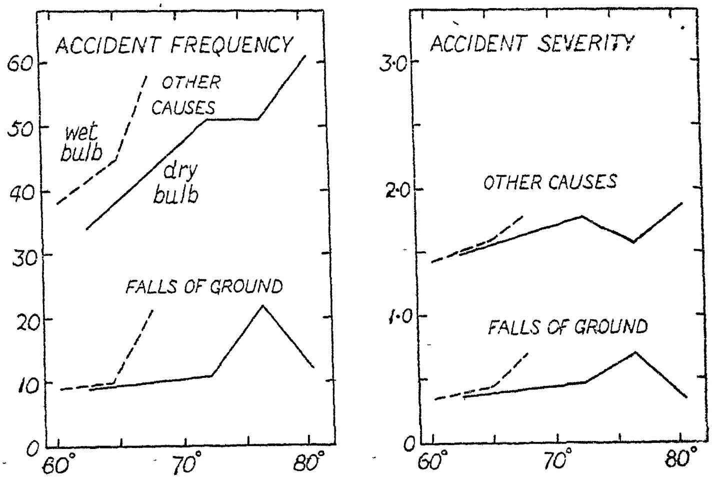

Fig. 6. Accidents to other underground workers in relation to temperature.

When the data were grouped according to the dry bulb and the wet bulb temperature, the mean results plotted in Fig. 6 were obtained. It will be seen that the frequency of accidents from both causes increased rapidly with rise of temperature, being nearly double as great at the highest dry bulb temperature experienced as at the lowest. The variations in accident severity were considerably smaller, or in other words, at high temperatures the number of minor accidents increased rather than the number of major ones. This differential effect of temperature on minor and major accidents was observed in relation to other conditions as well. It is a fact of such great importance as to dominate the interpretation placed by us upon most of our absenteeism data, whether they relate to absenteeism from accidents, sickness, or from voluntary causes. Before we describe the differential effects in detail, it is desirable that we should adduce some abutting evidence relating to the differential action of certain economic circumstances upon the apparent number of accidents of various degrees of severity.

Our first piece of evidence is drawn from the Annual Report of the Secretary for Mines (1926) concerning accident frequency in relation to the earnings of miners. The data recorded on the left side of Table XVIII, which were extracted from this report, show that between the years 1920 and 1925 the number of severe accidents (fractures, dislocations, and other severe personal injuries; also accidents due to explosions and to overwinding) incurred by British miners was very steady. Reckoned per 1,000 persons employed, it varied only from 3·5 to 4·3 (after correcting the 1921 figure for the three months lost by a coal dispute). On the other hand, the number of minor accidents varied considerably, for they were 26 times more numerous than the major accidents in 1920, but rose rapidly in later years till they were 40 times more numerous in 1925. Accompanying this rise in the relative proportion of minor accidents, the earnings of the miners underwent a rapid fall, and in 1925 they averaged only three-fifths their 1920 figure. However, this was partly compensated for by the fall in the cost of living, which in 1922 to 1925 ranged from 76 per cent. to 73 per cent. of its 1920 figure.

TABLE XVIII.—*Accident frequency in relation to earnings.*

Year.		Great Britain (all coal miners).			Accident frequency to coal face workers at colliery		Relative earnings per shift at colliery.	
		Severe accidents incurred.	Minor accidents for each major accident.	Yearly earnings in £.	A	B	A.	B.
Basis of over 7 days	1920	3·5	26	223	46	84	85	100
	1921	3·6*	27	192*	53	73	87	98
	1922	4·1	38	125	82	95	64	70
	1923	4·3	39	134	86	104	59	64
Basis of over 3 days	1924	4·0	39	138	68	137	65	72
	1925	3·9	40	132	99	132	60	64

* Corrected for time lost by coal dispute.

On the right side of Table XVIII, we record the relative earnings of the coal face workers at two of the collieries investigated by us, and they show a similar fall between the years 1920 and 1925. We did not attempt to split up the accidents on the scheme employed by the Mines Department, but the frequencies recorded in the Table show a rapid rise at each colliery from 1920 onwards, and there can be no doubt that the rise related to minor accidents rather than major ones.

The explanation of the variations in the frequency of accidents is suggested by the Coal Commission (1926). The Commissioners point out, with reference to the increase of accidents, that " there is some, though not conclusive ground, for connecting their number with the state of employment : the prospect of low and irregular earnings tends to keep the men on compensation longer than they would be if employment was plentiful and wages high." That is to say, the decision of the miner to remain on compensation or go back to work is influenced by considerations other than those dependent on the plain question of recovery from an injury. In fact, it appears to be influenced not only by economic considerations, but by many other considerations such as the conditions under which the miner is working and his environment in general. Such conditions have an influence, not only on the question of return to work, but even more on the question of claiming compensation at all. Few if any conditions are more important in this respect than the atmospheric conditions experienced underground.

Support of this statement was obtained by analysing the frequency of occurrence of accidents causing various durations of absence. Accidents were classified according as they provoked an absence of less than 10 working days, of 10 to 19 days, 20 to 59 days, or of 60 days (10 weeks) or more. We see from Table XIX that coal face workers, when working at a mean dry bulb temperature of 64·4 deg., incurred 3·6 accidents of less than 10 days' duration, owing to falls of ground. At a temperature of 77·3 deg., however, the number of such accidents rose to 9·5, and at 82·1 deg., to 18·2. Taking the number of accidents incurred at the lowest temperature as 100, it rose to 264 and 506 respectively at the higher temperatures. But when we consider the accidents causing a disability of 10 to 19 days, we find less than half as much increase at the higher temperatures, and when we consider major accidents causing a disability of 60 days or more, we find that the frequency was entirely unaffected by temperature. Accidents due to causes other than falls of ground were similarly affected, except that the major accidents incurred at high temperatures were less numerous than those incurred at low temperatures. When the accident disabilities were calculated in relation to wet bulb temperature instead of in relation to dry bulb temperature, a similar effect was observed, both as regards accidents from falls of ground and from other causes. All these results are plotted out in Fig. 7, where the differential effect of increasing temperature on minor and on major accidents is clearly revealed.

TABLE XIX.—*Accident disability of coal face workers in relation to temperature.*

Duration of absence.		Dry bulb temperature.						Wet bulb temperature.							
		Accident frequency at			Relative frequency at			Accident frequency at				Relative frequency at			
		under 70°	70° to 79°	80° or more	under 70°	70° to 79°	80° or more	under 66°	66° to 69°	70° to 73°	74° or more	under 66°	66° to 69°	70° to 73°	74° or more
(Mean temperature)		64·4°	77·3°	82·1°	—	—	—	61·8°	69·3°	71·9°	74·6°	—	—	—	—
Falls of ground	Under 10 days	3·6	9·5	18·2	100	264	506	3·7	13·0	13·1	15·2	100	351	354	411
	10 to 19 days	11·3	17·4	23·0	100	154	204	11·3	17·7	21·9	20·1	100	157	194	178
	20 to 59 days	11·5	14·4	22·2	100	125	193	11·5	15·8	15·7	22·0	100	137	137	191
	60 or more days	5·4	5·0	4·9	100	93	91	5·2	3·8	5·0	5·4	100	73	96	104
Other causes	Under 10 days	6·8	13·9	21·2	100	204	312	6·8	13·6	14·8	22·0	100	200	218	324
	10 to 19 days	14·7	23·7	23·8	100	161	162	14·7	20·2	20·9	27·9	100	137	142	190
	20 to 59 days	18·6	18·3	20·4	100	98	110	18·6	18·0	15·8	24·2	100	97	85	130
	60 or more days	6·3	2·8	3·2	100	44	51	6·3	3·5	2·0	3·6	100	56	32	57

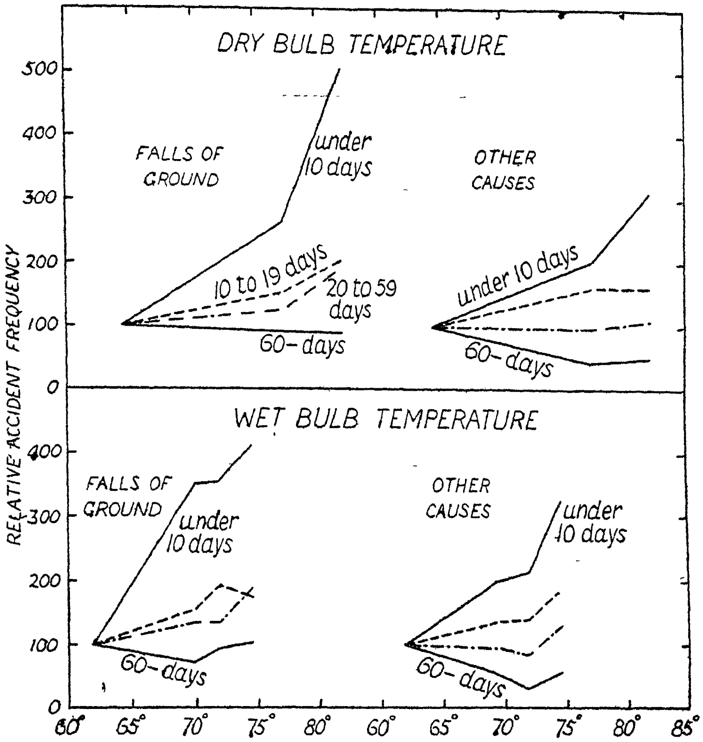

FIG. 7. Accident disability of coal face workers in relation to temperature.

When the accidents to other underground workers were classified on the same principle, the results recorded in Table XX were obtained. It will be seen that they show a similar differential effect of high temperature upon minor and major accidents. The effects of the highest mean temperatures observed upon the relative frequency of various minor and major accidents, both to coal face workers and to others were as follow :—

	Relative frequency, that at low temperatures being 100.	*Mean.*
Minor accidents (less than 10 days' disablement)	506, 312, 411, 324, 611, 438, 509, 361	434
Major accidents (60 days or more of disablement)	91, 51, 104, 57, 108, 103, 117, 146	97

On an average, therefore, the major accidents were almost exactly as numerous at the highest underground temperatures observed as at the lowest, whilst minor accidents were more than four times as numerous. This huge excess of minor accidents, together with the smaller excess shown by accidents causing intermediate degrees of disability, was presumably due to the injured men who worked at high temperatures claiming compensation more frequently than those working at low temperatures. Some idea of the extra time lost by these additional compensation

TABLE XX.—*Accident disability of other underground workers in relation to temperature.*

Duration of absence.		Dry bulb temperature.						Wet bulb temperature.					
		Accident frequency at			Relative frequency at			Accident frequency at			Relative frequency at		
		under 70°	70° to 74°	75° or more.	under 70°	70° to 74°	75° or more.	under 62°	62° to 65°	66° or more.	under 62°	62° to 65°	66° or more.
(Mean temperature) ..	..	62·6°	72·3°	77·0°	—	—	—	60·2°	65·0°	67·6°	—	—	—
Falls of ground	Under 10 days ..	0·9	2·4	5·5	100	267	611	1·1	2·7	5·6	100	245	509
	10 to 19 days ..	2·1	4·0	7·5	100	190	357	3·9	3·3	7·7	100	85	197
	20 to 59 days ..	4·4	3·2	6·0	100	73	136	3·0	3·1	6·3	100	103	210
	60 or more days ..	1·2	1·4	1·3	100	117	108	1·2	1·2	1·4	100	100	117
Other causes	Under 10 days ..	2·9	8·3	12·7	100	286	438	3·8	7·8	13·7	100	205	361
	10 to 19 days ..	12·7	18·2	20·0	100	143	157	14·9	14·6	22·4	100	98	150
	20 to 59 days ..	15·7	20·7	16·6	100	132	106	16·7	18·7	18·3	100	112	110
	60 or more days ..	3·3	3·6	3·4	100	109	103	2·6	3·4	3·8	100	131	146

claims was obtained by assuming that the men working at the lowest temperatures went on to compensation no more and no less than their injuries warranted, and calculating the extra time taken at higher temperatures. As an average of the results obtained with the coal face workers and others underground, it was found that accidents of less than 10 days' duration involved a mean absence of 6 days. The number of these minor accidents (of all kinds) incurred by the men at low dry bulb temperatures totalled 14·2, but at intermediate temperatures they came to 34·1, or 19·9 extra, and at high temperatures they came to 57·6, or 43·4 extra. It can be calculated that these extra claims involved the loss of 379·8 extra days, and it will be seen from Table XXI that similar calculations applied to accidents of 10 to 19 days' duration involved the loss of 806 4 extra days. Altogether 1,852 extra days were taken, as compared with the 4,306 days taken on the minimum basis observed at low temperatures. In calculating this minimum, it was assumed that the frequency of accidents of 60 or more days' duration was 13·9 (i.e., the mean of the frequencies observed at all temperatures), whilst the average duration (149·1 days) was calculated by ignoring fatal accidents altogether, but counting the full time of absence from work, even if it lasted a year. It follows, from the figures quoted, that nearly one-third of the total accident absenteeism was due to additional compensation claims over and above the minimum made on the low temperature basis, or in other words, it failed to earn the customary title of "unavoidable."

Why is it that the men working at high temperatures felt so powerful an inclination to go on to compensation when they incurred an injury? Probably the adverse atmospheric conditions induced a feeling of additional fatigue, from which they desired a temporary relief. It seems likely that sickness absenteeism is subject to the same qualification as accident absenteeism, if not a greater one, though we did not obtain any evidence on the subject.

In our previous investigation (1926) we found that the accident severity rate of the coal face men at Colliery A showed as great an increase at high temperatures as the frequency rate did, though the other underground men responded differently in respect of severity and of frequency. However, it is obvious that the present results, applying as they do to ten times the number of coal face workers then tested, and distributed over ten collieries, are much more reliable. At the same time, there can be no doubt that at very high temperatures the number of major accidents must tend to increase, as well as the minor ones. At the Morro Velho gold mine in Brazil, for instance, the number of fatal accidents incurred in the 16 months previous to the introduction of a cooling plant was 20, as contrasted with 6 in the succeeding 16 months. The plant cooled the intake air to 43 deg., and thereby reduced the temperature in the lowest workings from 89 deg. (wet bulb) to 80 deg. (Davies, 1922).

TABLE XXI.—*Time lost by accident disablement at various temperatures.*

Duration of absence.	Mean duration of absence.	Frequency of accidents incurred at			Minimum days lost.	Additional days lost.
		Low temperatures.	Intermediate temperatures	High temperatures.		
Under 10 days ..	6·0	14·2	34·1	57·6	6·0 × 14·2 = 85·2	6·0 × (19·9 + 43·4) = 379·8
10 to 19 days ..	14·4	40·8	63·3	74·3	14·4 × 40·8 = 587·5	14·4 × (22·5 + 33·5) = 806·4
20 to 59 days ..	31·1	50·2	56·6	65·2	31·1 × 50·2 = 1561·2	31·1 × (6·4 + 15·0) = 665·5
60 or more days ..	149·1	16·2	12·8	12·8	149·1 × 13·9 = 2072·5	
Total ..	—	—	—	—	4306·4	1851·7

(b) *Depth of Workings and Thickness of Seam.*

It can be seen from Table XI that there is a close correspondence between temperature and depth of workings. The correlation coefficients were extremely high, especially that for dry bulb temperature :—

Between depth and dry bulb temperature $r = +\cdot 952 \pm \cdot 015$
" " " wet " " $r = +\cdot 898 \pm \cdot 032$

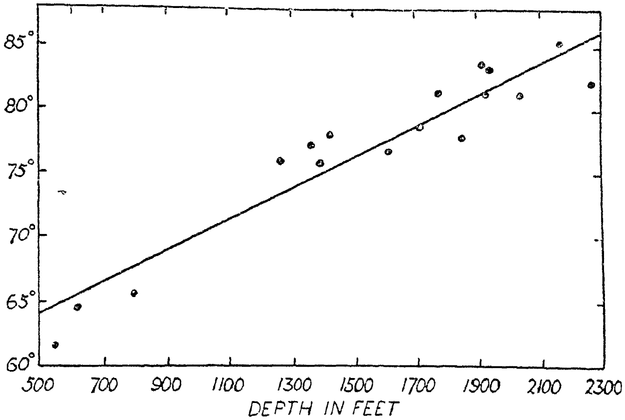

FIG. 8 Dry bulb temperature in relation to depth of workings.

The results obtained at the 17 seams are plotted in Fig. 8, where it will be seen that the individual values correspond closely with the regression line of temperature on depth. The regression equations of temperature on depth indicated that for each 1,000 ft. increase of depth there was an average rise of 12·7 ° F. in dry bulb temperature, and of 8·4° F. in wet bulb temperature, whilst the regression equations of depth on temperature indicated that for each rise of 1° F. in dry and wet bulb temperatures there was an average increase in depth of 71·6 and 96·1 ft. respectively. The following relationships between dry bulb temperature and depth were deduced from the equation :—

Depth of workings.	*Dry bulb temperature.*
500 ft.	63·6° F.
1,000 ft.	70·0° F.
1,500 ft.	76·3° F.
2,000 ft.	82·6° F.
2,500 ft.	89·0° F.

It has been calculated that the standard error of estimation of temperature on depth is 2·06° F. That is to say, if the depth of the workings in any seam of the ten pits investigated is known, the dry bulb temperature of the air can be predicted with an *average* error of only 2 deg.

TABLE XXII.—*Correlation of accident rates of coal face workers with depth.*

Cause of accidents.	Accident frequency.	Accident severity.
Falls of ground..	+·614 ± ·072	+·305 ± ·105
Other causes	+·286 ± ·106	−·046 ± ·115
All causes	+·538 ± ·082	+·225 ± ·110

The correlations of the accident rates of coal face workers with depth are recorded in Table XXII. It will be seen that accidents from falls of ground are highly correlated in respect of frequency, and to a much less extent in respect of severity. On the other hand, accidents from other causes, if considered in relation to severity as well as frequency, cannot be said to have any significant correlation with depth. The corresponding correlations for other underground workers are not recorded, as it was impossible to determine the average depth at which the men were working with sufficient exactness.

The relationships observed at the individual seams between the frequency of accidents from falls of ground and the depth are plotted in Fig. 9. It will be seen that there is a fairly good correspondence with the regression line. Assuming that this line correctly represents the relationship between accidents from falls of ground and depth, we calculated from the regression equation that the mean accident frequency at a depth of 500 ft. was 27, whilst that at a depth of 2,300 ft. was 67, or 2½ times as much.

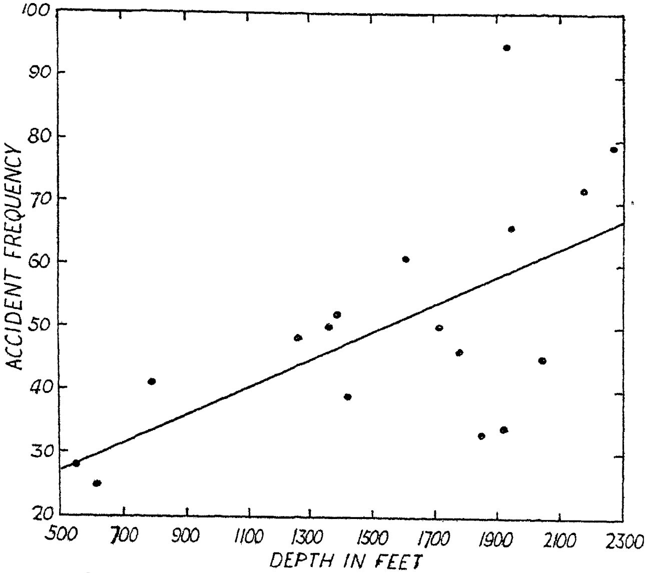

FIG 9. Frequency of accidents from falls of ground in relation to depth of workings.

TABLE XXIII.—*Accident rates of coal face workers in relation to depth.*

Range of depth	Mean depth (feet).	Accident frequency.			Accident severity			Total shifts worked
		Falls of ground.	Other causes	All causes	Falls of ground	Other causes	All causes	
Under 1,000 ft	670	32	46	78	1·5	1·9	3·4	381,169
1,000 to 1,499 ft ..	1,352	47	53	100	1·9	1·5	3·4	673,440
1,500 to 1,999 ft ..	1,822	57	61	118	1·9	1·7	3·6	1,895,563
2,000 ft. or more .	2,183	67	76	143	2·3	2·1	4·4	942,503

On classifying the data according to the depth and irrespective of the pit, the mean results recorded in Table XXIII were obtained. They are plotted in Fig. 10, and it will be seen that the frequency of accidents from "other causes" increased fairly regularly with depth, though not so rapidly and regularly as those from falls of ground. However, the severity rate of accidents from other causes showed no consistent relationship to depth.

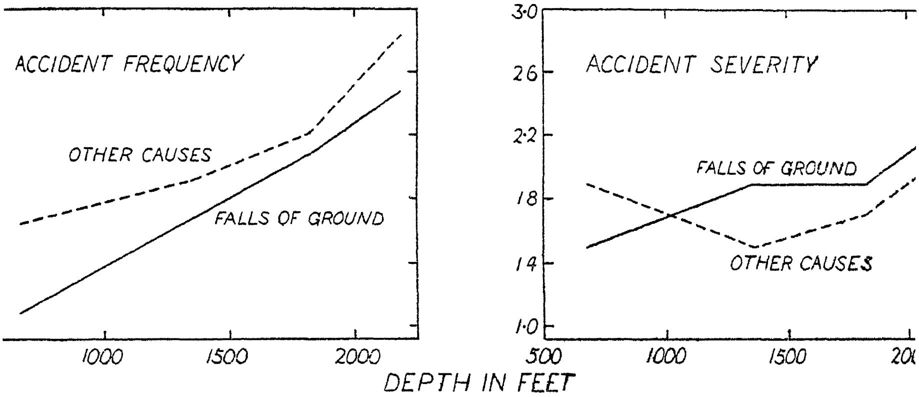

FIG 10. Accidents of coal face workers in relation to depth of workings.

As depth and temperature are so highly correlated, it follows that the association of depth with accidents involving various durations of absence is similar to that observed for temperature. In Table XXIV the frequencies of accidents from falls of ground and from other causes are recorded in relation to depth. From the relative numbers given on the right side of the Table, it will be seen that at an average depth of 2,183 ft. minor accidents, lasting less than 10 days, were more than four times as numerous as at a depth of 670 ft. Major accidents from falls of ground, lasting 60 days or more, were uninfluenced by depth, whilst those due to other causes were considerably less frequent in deep pits than in shallow ones. The reason of this is unknown. Accidents involving an intermediate degree of disability showed an intermediate response to depth, as can be gathered from the curves plotted in Fig. 11.

TABLE XXIV.—*Accident disability of coal face workers in relation to depth.*

Duration of absence.		Accident frequency at depth of				Relative frequency at depth of			
		under 1,000 ft	1,000 to 1,499 ft	1,500 to 1,999 ft	2,000 ft or more	under 1,000 ft.	1,000 to 1,499 ft	1,500 to 1,999 ft.	2,000 ft or more.
(Mean depth)		670	1,352	1,822	2,183	—	—	—	—
Falls of ground	Under 10 days	3 7	7 1	14 4	18 0	100	192	389	486
	10 to 19 days	11 3	18 4	20 1	22 0	100	163	178	195
	20 to 59 days	11 5	15 2	18 0	21 8	100	132	157	190
	60 days or more	5 2	6 1	4 3	5·4	100	117	83	104
Other causes	Under 10 days	6 8	11·6	16 5	24 4	100	171	243	359
	10 to 19 days	14 7	20 9	23 5	26·4	100	142	160	180
	20 to 59 days	18 6	18 4	18 3	22 3	100	99	98	120
	60 days or more	6 3	2 4	3 1	3 2	100	38	49	51

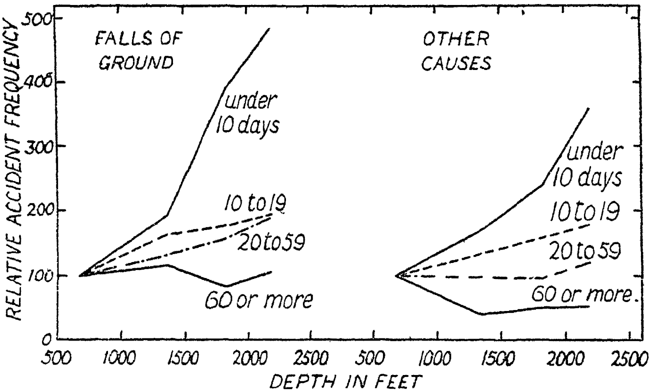

FIG 11. Accident disability of coal face workers in relation to depth of workings.

The accident rate is greatly influenced by the thickness of the coal seam, the greater the thickness the greater being the frequency in the falls of coal and of side. We ascertained the average thickness of the seams at the 17 localities recorded in Table XI, and found that it varied between 36 and 72 inches. The correlation coefficients were :—

For accident frequency from falls of coal with thickness of seam .. .. $r = +\cdot 707 \pm \cdot 058$

For accident severity from falls of coal with thickness of seam .. . . $r = +\cdot 665 \pm \cdot 065$

For accident frequency from falls of roof with thickness of seam .. .. $r = -\cdot 149 \pm \cdot 113$

It will be seen that there was no significant correlation between accident frequency from falls of roof and thickness of seam.

A more satisfactory method of demonstrating the relationship between accident rate and thickness of seam is to keep to the same seam throughout. The E seam, which we investigated at six collieries, varied in average thickness from 44 to 72 in., and it will be seen from the data adduced in Table XXV that the accident rate from falls of coal and side (which formed 40 per cent. of all accidents from falls of ground) varied in close correspondence with the thickness. Frequency and severity were affected almost equally, the rate of each of them being more than four times greater when the seam was at its thickest than when at its thinnest.

TABLE XXV.—*Accidents through falls of coal and side in relation to thickness of seam.*

Colliery.	Depth of workings.	Thickness of seam.	Accident frequency	Accident severity.
	Ft.	In.		
P	1,850	44	9·0	0·32
N	1,386	50	12·7	0·45
L	2,269	66	27·8 } 29·9	0·97 } 0·99
Q	1,260	66	32·0	1·01
M	1,420	72	32·4 } 37·0	1·04 } 1·30
J	1,608	72	41·6	1·56

It follows from this correspondence between frequency and severity rates that the influence of thickness of seam was as great on major accidents as on minor accidents. This deduction is supported by the disability figures recorded in Table XXVI. They are rather irregular, owing to the fact that there were only 17 sets of data altogether (i.e., one for each of the 17 seams investigated), but it will be seen that accidents of all durations were about four times more numerous when 72-in. seams were being worked than with 36- to 48-in. seams. This similarity of effect on accidents involving all degrees of disability is what one would expect, for there was no correspondence between thickness of seam and depth. That is to say, the atmospheric conditions at thick seams were neither better nor worse than those at thin seams, so there was no greater inducement for the men who incurred minor accidents to go on compensation more frequently if they worked at thick seams than at thin ones.

Since there was no correspondence between atmospheric conditions and thickness of seam, it follows that the association between accident rates and atmospheric conditions cannot have been influenced by the thickness of the seams.

TABLE XXVI.—*Accident disability from falls of coal in relation to thickness of seam.*

Duration of absence.	Accident frequency at seams of					Relative frequency at seams of				
	36″ to 48″.	50″ to 54″.	60″ to 63″.	66″.	72″.	36″ to 48″.	50″ to 54″.	60″ to 63″.	66″.	72″.
Under 10 days ..	2·6	2·7	1·9	9·2	11·4	100	104	73	354	438
10 to 19 days ..	3·8	5·8	4·8	10·4	12·1	100	153	126	274	318
20 to 59 days ..	2·5	5·1	7·1	10·1	10·8	100	204	284	404	432
60 days or more	0·8	0·8	2·0	1·7	3·9	100	100	250	213	487

The results recorded in Table XXVI, in spite of their irregularity, afford a valuable support to the correctness of the explanation given for the excess of minor accidents experienced under adverse atmospheric conditions in the pits.

It is interesting to note that in 1909 the Committee on Accidents of the Royal Commission on Mines found that the death-rate from falls of ground of persons employed underground in South Staffordshire was much higher in thick seams than in thin ones. In the very thick seams (over 15 feet) the death-rate was 2·3 per 1,000, and in the thin seams, 0·8

(c) *Output per Man.*

The output of the miners at the various pits differed considerably, and at most of the collieries we were able to obtain information concerning the average output per man (at the coal face) per shift. This information is recorded in Table XXVII in a relative form for the years 1924 and 1925. It will be seen that the means of the two years' results vary between the extremes of 68 and 137, or as 1 to 2. The accident frequency data are likewise recorded, and it is evident that there is a rough correspondence between the two. The correlation coefficient of output with accident frequency was, in fact, rather high.

For output with accidents from falls of ground $r = +\cdot615 \pm \cdot079$
,, ,, ,, ,, ,, other causes $r = +\cdot340 \pm \cdot113$
,, ,, ,, ,, ,, all causes $r = +\cdot580 \pm \cdot084$

TABLE XXVII.—*Accident frequency of coal face workers in relation to output.*

Colliery and seam.	Depth in feet.	Thickness of seam worked, in inches.	Relative output.			Accident frequency from		
			1924.	1925.	Mean.	Falls of ground.	Other causes.	All causes.
N, H	546	54	65	71	68	28	75	103
A (1), C	616	60	93	98	96	25	38	63
N, G	791	36	85	90	87	41	42	83
N, E	1,386	50	88	86	87	52	59	111
M, E	1,420	72	102	115	108	39	57	96
A, D	1,581	63	81	78	79	48	46	94
J, E	1,608	72	140	133	137	61	67	128
K, D	1,715	54	114	109	112	50	102	152
P, E	1,850	44	95	84	89	33	39	72
M, D	1,930	66	133	133	133	93	66	159
B, D	1,942	60	121	107	114	66	73	139
K, F	2,042	48	84	82	83	45	74	119
B, F	2,168	54	85	90	87	72	59	131
L, E	2,269	66	121	119	120	79	82	161

The relationships observed for the individual seams between output and accidents from falls of ground are plotted in Fig. 12, and it will be seen that the values agree fairly well with the regression line.

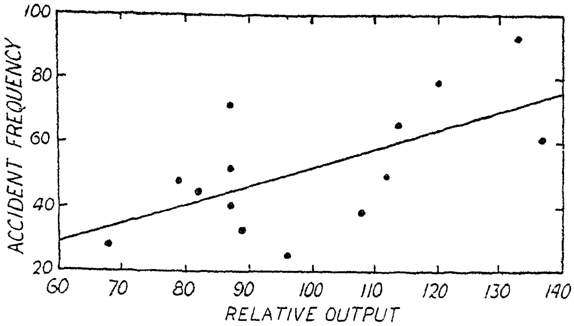

FIG 12 Frequency of accidents from falls of ground in relation to output

Other correlation coefficients calculated from the observations recorded in Table XXVII were the following :—

For depth with accidents from falls of ground .	$r = +\cdot 702 \pm \cdot 065$
For output with depth . .	$r = + 410 \pm \cdot 106$
For output with thickness	$r = +\cdot 624 \pm 078$

It might be thought that the positive correlation of output with depth is opposed to our previous observations (1927), in which we found that the working capacity of the miners is considerably reduced at high temperatures. The explanation of the apparent contradiction depends on the fact that the coal of the deepest seam investigated, the D seam, is softer and more easily extracted than that of the E seam lying above it, whilst that of the shallow C seam is hard steam coal, difficult to extract.

The high positive correlation between output and thickness suggests that much of the increase of accidents associated with higher output should really be ascribed to the influence of the thick seams.

When the accidents were classified according to their duration, it was found that the effect of rate of output on frequency was practically confined to minor accidents From Table XXVIII, which shows the accident frequency from all causes at seams where various outputs were attained, it will be seen that at pits where the output was 120 or more, the minor accidents—causing less than 10 days' disablement—were three times more numerous than at pits where the output was 80 or less. Accidents causing 10 to 19 days' disability showed a moderate increase with increasing rate of output, whilst accidents causing 20 days or more of disability were practically independent of output. This relationship held equally for accidents from falls of ground and from other causes, but we thought it unnecessary to record the separate sets of data. This increase of minor accidents with increase of output may be dependent on the above-mentioned correlation of output with depth. We saw previously that minor accidents increased with increase of depth, and consequently they likewise increase with increase of output.

TABLE XXVIII.—*Accident disability in relation to output per man.*

Duration of absence	Accident frequency when output was					Relative frequency when output was				
	Under 80	80 to 89	90 to 109	110 to 119	120 or more	Under 80	80 to 89.	90 to 109	110 to 119.	120 or more
Under 10 days	15	21	18	45	46	100	140	120	300	307
10 to 19 days	31	39	34	53	51	100	126	110	171	165
20 to 59 days	50	32	34	47	41	100	64	68	94	82
60 days or more	12	7	10	9	9	100	58	83	75	75

Related to the subject of rate of output is the rate of advance of the coal face. It is stated by the Safety in Mines Research Board (1926) that risks at the working face usually diminish as the rate of advance increases We were able to obtain information about the rate of advance of the coal face at all the collieries investigated except one, and we found that it showed great variations. In the E seam it ranged from 70 to 140 yds. per year, in the D seam, from 80 to 150 yds , and in the F seam, from 120 to 380 yds. The correlation between rate of advance of coal face and accident frequency was insignificant, as the following coefficients show :—

For rate of advance of face on accidents from all falls of ground . .. . . $r = -\cdot 147 \pm 129$

For rate of advance of face on accidents from falls of roof only .. .. $r = + 020 \pm 132$

When, however, all the available data from the various pits were grouped together, and classified according to the average rate of advance, the accidents (from all falls of ground) showed a distinct diminution of frequency with increasing rate of advance. As can be gathered from the data recorded in Table XXIX, the rate diminished less in respect of minor accidents than in respect of major ones.

TABLE XXIX.—*Accident frequency in relation to rate of advance of coal face.*

Duration of absence	Frequency when rate of advance was					Relative frequency when rate of advance was				
	80 yds or less.	101 to 120 yds	121 to 140 yds.	141 to 160 yds	380 yds	80 yds or less	101 to 120 yds	121 to 140 yds	141 to 160 yds	380 yds
Under 20 days	34	39	39	27	28	100	115	115	79	82
20 to 59 days	21	21	15	14	13	100	100	71	67	62
60 days or more	6 2	5 2	4 8	3 7	3 6	100	84	77	60	58

Another matter indirectly related to rate of output is labour turnover. As will be shown hereafter, the labour turnover at the various pits investigated varied between the extremes of 9·6 per cent. and 33·6 per cent. per annum, and it seems reasonable to assume that if the labour turnover is large (in respect both of men leaving and of new men taken on), the men are less contented with the conditions of work than if it is small. When we classified the accidents of the coal face workers according to the labour turnover at the pit at which they were incurred, we obtained the results recorded in Table XXX We see that minor accidents causing less than 20 days' disability were three times more numerous at pits where there was a labour turnover of 20 per cent. or more than at those where it was less than 10 per cent. Accidents causing 20 days or more of disability were, however, unaffected by the labour turnover of the pit.

TABLE XXX—*Accident disability of coal face workers in relation to labour turnover*

Duration of absence	Accident frequency when labour turnover was				
	Under 10 per cent.	10 to 19 per cent.	20 to 29 per cent	30 to 39 per cent.	40 per cent. or more.
Under 20 days . .	26	49	84	78	81
20 to 59 days .	40	30	43	28	42
60 days or more. .	14	8	9	6	8

(d) *The Age of the Men*

It is well known that the accident rate tends to decrease as the experience and age of the workers increase. For instance, Chaney and Hanna (1918) found that the accidents suffered by the men employed at a large steel works fell steadily with length of service, till it reached zero with men of over 15 years' service. Kitson and Campbell (1923), who obtained information relating to 29,000 accidents incurred in the manufacture of motor cars, railway cars, cutlery, and coke and gas, found that the accident rate varied synchronously with the number of new men employed. No attempt was made in either of these investigations to distinguish between the effects of experience and of the age of the workers, but Miss E. M. Newbold (1926), in her statistical study of the accidents incurred in a number of industrial occupations, such as the manufacture of machinery, motor cars, soap, and confectionery, came to the conclusion that age is a more important factor than experience The accidents certainly diminished with experience, but when allowance was made for age there was no independent association between experience and accidents. However, her data did not include many absolutely new workers. In a few instances the accident rate reached a minimum at an age of 47 to 65, and rose at greater ages, but as Miss Newbold points out, the numbers of accidents at the higher ages are too few for the rise to be of any significance when considered alone, though its agreement with a similar rise of the accident mortality rates among older workers is suggestive.

As previously stated, we were able to calculate the age distributions of the men at all the collieries in 1924 and 1925 from our information about the ages of the men signing on after the coal disputes of 1921 and 1926. As the age of every man coming under compensation is recorded at the time of his accident, we were able to calculate the accident rates at various ages with considerable accuracy. The mean results are recorded in Table XXXI, and are plotted in Fig 13. It will be seen that both with the coal face workers and the other underground workers the accidents reached a minimum at an age of about 30, and rapidly increased at higher ages. At an age of 60 or more coal face workers suffered 41 per cent. more accidents than at 30–39, and as their accident severity rate was 100 per cent. greater, it follows that for each accident incurred by the older men there was, on an average, a much greater loss of working time. Owing to the large number of men concerned and to the fact that they were all employed on work of the same character, whatever their age, it follows that considerable reliance can be placed on the correctness of this variable relationship between accident rate and age. The same claim cannot be made for the accident rates of the other underground workers. as the occupations of these men varied greatly with age. The younger men were mostly occupied on haulage work of various kinds, and the older ones, upon light repairing jobs on the roads, and on overseeing the other men. Men engaged in drifting (driving new roads) and ripping (removing ground from the roof) were usually of intermediate age. We do not know to what extent the accident risks of these men varied with occupation, but from the results recorded in Table XXXI it is clear that, taken as a whole, their risks were much less than those of the coal face workers.

TABLE XXXI —*Accidents in relation to the age of the men.*

		Age group.					
		Under 20.	20 to 29	30 to 39	40 to 49	50 to 59	60 and over.
Coal face workers	Number employed	263	2,838	2,626	1,921	934	189
	Frequency ..	312	264	232	268	283	327
	Relative frequency	134	114	**100**	116	122	141
	Severity .. .	6·06	5·45	5·31	7·26	8·37	10·60
	Relative severity	114	103	**100**	137	158	200
Others underground	Number employed	3,363	2,496	1,297	1,132	849	397
	Frequency ..	199	139	140	157	145	157
	Relative frequency	142	99	**100**	112	104	112
	Severity ..	4·67	3·10	3·67	4·24	4·64	5·48
	Relative severity	127	84	**100**	116	126	149

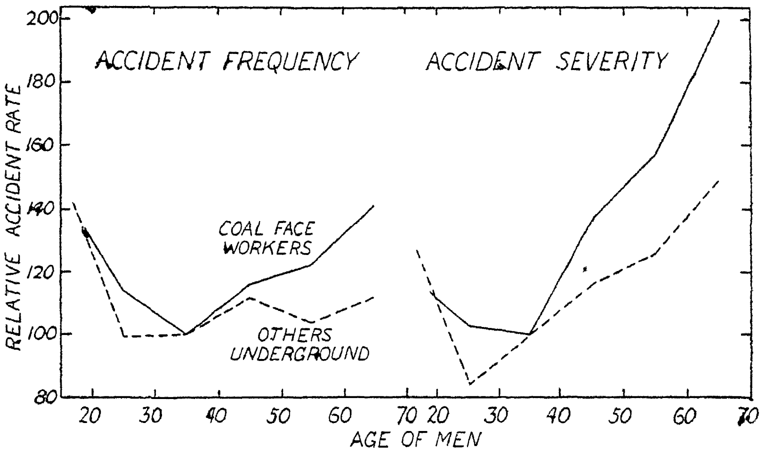

FIG 13. Accident rates in relation to the age of the men

It may be wondered why the relationship of accident rate to age in coal miners differs so considerably from that observed in other industrial workers. Probably it is due to the arduousness of the coal miners' work. Accidents tend to diminish with age, because the older men are usually more skilful and more careful than the younger men; but on the other hand they are more easily fatigued, and fatigue may lead to accidents.

Another method of showing that, the older the men, the longer the duration of their accident disability, was to classify the accidents incurred at various ages according as they led to a disability of less than 20 days, of 20 to 59 days, and of 60 days or more. It will be seen from Table XXXII that whilst 67 per cent. of the accidents incurred by the youngest men (coal face workers) lasted under 20 days, only 48 per cent. of those incurred by men of 50 and upwards had a similar duration. On the other hand, accidents causing a disability of 60 days or more formed but 5 per cent. of the accidents to the youngest men, as against 11 per cent. of those to the oldest men.

TABLE XXXII—*Accident disability in relation to age of men (coal face workers)*

Age of men.	Percentage of accidents causing absence of			Number of accidents		
	under 20 days.	20 to 59 days.	60 days or more.	under 20 days.	20 to 59 days	60 days or more.
Under 30 years .	67	28	5	1,108	476	77
30 to 39 years . .	65	28	7	793	346	77
40 to 49 years . .	56	35	9	580	354	97
50 or more years .	48	41	11	314	269	68

(e) *Hour of Shift.*

The influence of fatigue in the causation of accidents is suggested by the frequency with which accidents occur during the progress of the shift. The time at which an accident happened was always recorded, and from these records we determined the frequency from hour to hour of the 7-hour shift. We split up our data according to the air temperature (under 70°, 70° to 79° or 80° and over), and the accidents per hour per 100,000 man-shifts are plotted in Fig. 14 It will be seen that amongst coal face workers they reached a maximum in the sixth hour of the shift when the temperature was low, and in the fifth hour when it was medium or high. As the miners work for only a portion of the last hour of the shift, their accident frequency during this hour may be ignored. Consequently it follows that at low temperatures the coal face workers attained their maximum accident frequency in the last hour of full work, whilst at high temperatures they attained it in the last hour but one. The other underground workers, whilst attaining maximum accident frequency in the last hour of full work at low temperatures, attained it one to two hours earlier when working at higher temperatures.

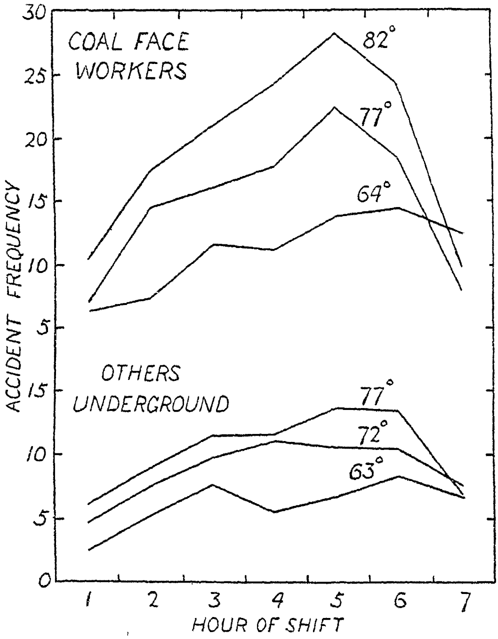

FIG 14 Accident frequency in relation to hours of shift

When the accidents were separated into those due to falls of ground and those due to other causes, they were found to give closely similar distributions in frequency during the course of the shift.

It should be stated that our data include the men working on all the shifts, whether morning, afternoon or night. When split up according to shifts, the distribution was very similar in all three. The morning and afternoon shifts were approximately equal in size, but the night shift was very much smaller.

5. Absenteeism due to "Voluntary" Causes.

The term "voluntary," as applied to absenteeism, is taken to imply all absenteeism which is not definitely attributed to accidents or to sickness. It is impossible to say how exact a measure it is of genuine voluntary absenteeism, because it suffers from an over-estimate in some directions, and an under-estimate in others. For instance, a man may suffer a minor injury which incapacitates him for two or three days, but if it does not prevent work for the minimum legal period of four days, he is not entitled to accident compensation. Again, a man may catch a cold and feel too ill to work for two or three days, but as he is not entitled to claim sickness benefit for the first three days of an illness, it is useless for him to obtain a doctor's certificate, and at collieries where such a certificate is demanded as a proof of sickness, his absenteeism counts as "voluntary." As already stated, this particular cause of error did not arise in the present observations, as the word of the individual miners was relied on, if considered satisfactory by the time keeper, but the judgment of time keepers is not infallible Again, if a miner arrives late at the pit head for any cause whatsoever, e.g., some breakdown in the transport from his home, he is not allowed to go underground, and loses his whole day's work. Amongst factory workers, however, late arrival is often condoned, and especially so if the lateness is not due to the worker's own fault.

On the other hand, we have seen that under adverse working conditions, such as high temperature, and even under adverse economic conditions, the men claim compensation for minor injuries far more frequently than when the conditions are more favourable, so in these instances a considerable fraction of the time ascribed to accident absenteeism should really have been classified as voluntary absenteeism.

The Coal Commission (1926) concluded that, taking all the coal areas of the country together, rather less time was lost voluntarily than by sickness and accidents combined. Our own data show that in the area tested by us the coal face workers lost 8·8 per cent. of their time from voluntary causes and 7 per cent. from sickness and accidents, whilst the other underground workers lost the same amount of time from both sets of causes, namely, 4·8 per cent. We shall see that the surface workers lost slightly less time voluntarily than from sickness and accidents, but as they formed only a fifth of the total number of men employed, it follows that the whole body of miners in the area investigated by us lost rather more time from voluntary causes than from involuntary ones. Hence it is a matter of great practical importance to discover what we can about the conditions which tend to influence voluntary absenteeism, with a view to its reduction.

(a) *Atmospheric Conditions*

The correlation tables previously recorded (pp. 8 and 10) indicate that there was little if any correlation between atmospheric conditions such as temperature, cooling power and air velocity, and the voluntary absenteeism of the coal face workers. On the other hand, the other underground men showed a substantial correlation in respect of temperature and air velocity. The correlation coefficient of voluntary absenteeism with wet bulb temperature was +·39, and on classifying the combined data obtained at all the pits according to the wet bulb temperature, it was found—as can be gathered from Table XXXIII—that a rise of 10 deg. in temperature was associated with nearly a doubling of the voluntary absenteeism. Air velocity appeared to have just as much influence as wet bulb temperature. The correlation coefficient of voluntary absenteeism with air velocity was +·45, and on combining and classifying the data it was found that the absenteeism was doubled when the air velocity rose from 137 ft. per minute to 264 ft. (*cf.* Table XXXIII)

The Table also indicates the proportions of the men living near to large towns. As will be shown later on, such proximity tends to augment their absenteeism, and the fact that the great majority of the men working at high air velocities lived near towns, whilst those working at low velocities did not, may be partly the cause of the increased absenteeism recorded. However, it will be seen that the adverse effect of high wet bulb temperature on absenteeism cannot be ascribed to this cause.

TABLE XXXIII.—*Voluntary absenteeism of other underground workers in relation to temperature and air velocity.*

Wet bulb temperature.		No of men	Percent living near large towns	Percentage of time lost	Air velocity in feet per min		No. of men	Percent living near large towns.	Percentage of time lost.
Range	Mean. °				Range	Mean.			
Under 62°	58·3	262	91	3·6	Under 120	90	1,837	32	4·6
62° to 65·9°	64·5	3,281	66	4·8	120 to 159	137	2,068	21	4·4
66° or more	67·7	3,451	52	7·0	160 to 199	171	1,244	94	5·2
					200 or more	264	1,819	97	8·8

The fact that coal face workers and other underground workers reacted so differently to atmospheric conditions may appear to discredit the reliability of the results. So far as concerns air velocity there is no contradiction, for we saw that, except at one pit, the air velocity to which the coal face workers were exposed never exceeded 80 ft. per minute; whilst with one exception, that to which the other underground men were exposed was always over 100 ft. The high air velocities appeared to induce sickness, for we saw that men exposed to a 264 ft. velocity lost twice as much time from this cause as those exposed to a 90 ft. velocity.

(b) *Distance of Workings from Pit Bottom.*

According to evidence furnished to the Royal Commission by the Mining Association,* the miners take on an average 23 minutes to get from pit bottom to coal face, but the time varies from 17 to 38 minutes in different districts, and in one pit it was over 60 minutes. When the distance from pit bottom to coal face is considerable, the men are frequently "ridden in" for part of the way, but admittedly they may sometimes have to walk over two miles. A long time spent in transit means a reduced time in which to get coal and a diminution of earnings, so it might be expected to cause discontent. We certainly found that it tended to increase the voluntary absenteeism of the men. We were able to determine the approximate distance which the men had to walk from pit bottom to coal face in seven of the pits, and it will be seen from Table XXXIV that it varied from 1,000 yds. to 2,860 yds. The average times lost from voluntary absenteeism appear to vary more or less in relationship with the distance walked, the correlation coefficient of absenteeism on distance walked being +·383 ± ·046. When the results were split into three groups according to the distance walked, and averaged, it was found that an addition of 1,482 yds. to the distance was associated with a 58 per cent. increase in the time lost by voluntary absenteeism.

TABLE XXXIV.—*Relationship between voluntary absenteeism and distance walked underground.*

Colliery.	Distance walked in yards		Percentage of time lost	
A (1), C	1,000	1,333	8·2	7·3
A (2)	1,500		7·0	
M	1,500		6·8	
A (1), D	2,000	2,307	8·9	8·4
L	2,420		12·5	
J	2,500		3·9	
K	2,770	2,815	11·3	11·5
N	2,860		11·7	

(c) *Labour Turnover.*

The extent of the labour turnover at a colliery affords some measure of the conditions under which the work is carried on. If the turnover is low the conditions are presumably satisfactory, and contented men are less likely to lose time by voluntary absenteeism than discontented men. If the turnover is high, it may be due to some extent to the age of the collieries, for the population takes time to settle down in a newly developed colliery district. For the same reason absenteeism would be affected by the age of the collieries. Again, newer pits tend to be deeper than older ones, so the greater absenteeism observed at deep pits might be due to some extent to the more unsettled character of the miners, and not to the higher temperature. We obtained information about the age of the collieries investigated by us, and this information is recorded in Table XXXV. It will be clear that there was no close relationship between labour turnover and the age of the collieries investigated

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In order to test the relationship between labour turnover and absenteeism, we obtained information (*a*) in regard to the number of underground men who left, reckoned as a percentage of the average number of men on the books , and (*b*) in regard to the number of new men signed on, reckoned as a similar percentage. We obtained these data for each of the years 1924 and 1925, and for purposes of comparison with the absenteeism data we took a mean of the turnover data for the two years.

TABLE XXXV.—*Labour turnover and voluntary absenteeism*

olliery.	Age of Colliery in years		Percentage of men						Percentage of time lost voluntarily			
			Leaving		Taken on.		Mean.		Coal face workers.		Others underground	
(2) .		60	4·9	11·4	10·0	7·8	7·5	9·6	7·0	8·0	2·8	3·2
(1), D			17·9		5·6		11·8		8·9		3·2	
(1), C			11·0		8·1		9·6		8·2		3·6	
.	10	16	18·0		23·3		20·7	20·8	3·9	8·2	3·0	5·9
. .	22		19·4		22·6		21·0		12·5		8·8	
.	55	59	26·2		25·8		26·0	27·1	6·8	9·9	4·6	5·6
. .	32		24·8		28·7		26·8		—		—	
. .	47		25 8		28·0		26·9		11·7		6·3	
.	100		28·6		28·3		28·4		11·3		6·0	
.	11		33·0		34·2			33·6	—		—	

The turnover at the various collieries—except at colliery Q, where data were not obtainable—is recorded in Table XXXV. It relates to all the underground workers put together, as it was not possible to separate them, and it will be seen that the percentages of men leaving and of new men taken on corresponded well at all the collieries except two. As the two collieries in question (A (2) and A (1), D) were connected underground and were working on the same seam, their turnover may be averaged. The means come to 11·4 per cent. of men leaving and 7·8 per cent. of new men. Hence it may be said that the correspondence between the numbers of men leaving and of new men taken on was fairly good at all the collieries, so a mean of the two values may be accepted as the best index of the turnover. It varied from a maximum of 33·6 per cent. to a minimum of 9·6 per cent.

The absenteeism of the coal face workers and of the other underground men had to be correlated with the labour turnover of the whole body of underground workers, and the coefficients obtained are recorded in Table XXXVI. It will be seen that there was little if any correlation between sickness and labour turnover, but that between voluntary absenteeism and labour turnover was quite distinct The relationships between voluntary absenteeism at the individual collieries and turnover are recorded in Table XXXV. It will be seen that as the result of splitting the data into three groups and averaging, it appears that a trebling of the labour turnover was associated with almost a doubling of the voluntary absenteeism in "others underground," and with a 24 per cent. rise in the coal face workers. Apparently, therefore, dissatisfaction with the conditions of work, as indicated by the labour turnover, had a considerable influence on voluntary absenteeism.

TABLE XXXVI.—*Correlation of absenteeism with labour turnover.*

Absenteeism on account of	No. of observations used in each correlation.	Coal face workers	Other underground men
Sickness . ..	155	−·071 ± ·054	−·135 ± ·053
Accidents	207	−·186 ± ·045	+·293 ± ·043
Voluntary causes ..	155	+·290 ± ·050	+·491 ± ·041
All causes	207	+·302 ± ·043	+·448 ± ·037

(d) *Distance of Homes from Colliery.*

In order to determine if voluntary absenteeism was influenced by the distance of the miners' homes from the colliery, we obtained details at each colliery of the number of men living in various localities. By measuring the distances on a large scale map, we were able to ascertain the average distance between the pit and the men's homes. As can be gathered from Table XL, it ranged between the extremes of 1·4 and 3 miles. The correlation between the average distance (of all underground workers) and the absenteeism of the coal face workers and others is recorded in Table XXXVII. It will be seen that the coefficients of voluntary absenteeism with distance were fairly high, being + ·61 and +·50 respectively, whilst those of distance with sickness were negative. That is to say, the further the men lived from the colliery the greater their voluntary absenteeism but the less their sickness. An explanation of this curious result is afforded by the correlation coefficients between the average age of the men and the average distance between homes and pit. For the eight collieries (or seams) where reliable sickness data were obtained, they were strongly negative, the coefficient between age and distance being − ·700 ± ·122 for coal face workers, and − ·710 ± ·118 for other underground workers These values indicate that the older men lived a good deal nearer to the colliery than the younger ones, and as they were more liable to sickness, it follows that the correlation of sickness absenteeism with distance of homes was negative.

TABLE XXXVII.—*Correlation of absenteeism with distance of homes from colliery.*

Absenteeism on account of	No of observations used in each correlation.	Coal face workers.	Others underground
Sickness	155	—·361 ± ·047	—·206 ± ·052
Accidents	228	—·042 ± ·045	+·355 ± ·039
Voluntary causes .	155	+·610 ± ·034	+·496 ± ·041
All causes	228	+·282 ± ·041	+·362 ± ·039

The relationship between age and distance is shown more directly in Table XXXVIII. It will be seen that the coal face workers living nearest to their respective collieries were nearly seven years older than those living furthest from them, whilst the other underground workers were two years older. That the older men were also the steadier men with a low labour turnover is indicated by the fact that there was a considerable negative correlation between age and labour turnover, the coefficient between age and labour turnover being — ·756 ± ·102 for coal face workers, and — ·385 ± ·203 for other underground workers. We see from Table XXIX that when the seams were classified according to the average age of the workers, the associated labour turnover ranged from 39 per cent. for the youngest coal face men to 10 per cent. for the oldest men, and from 32 per cent. for the youngest of the "others underground" to 18 per cent. for the oldest. Again, we see from Table XXXVIII that the labour turnover of the men living nearest to the collieries was not half as great as that of the men living furthest from them.

TABLE XXXVIII.— *Average age and labour turnover in relation to average distance of homes from colliery.*

Range of distance of homes from pit.	Average distance.	No. of seams.	Mean labour turnover of all underground men.	Average age in years.	
				Coal face workers.	Others underground.
			Per cent		
1·60 miles or less ..	1·59	5	19·3	37·9	29·7
1·61 to 2·10 miles ..	1·88	3	22·0	39·0	28·4
2·11 to 2·60 miles ..	2·29	3	23·6	36·4	29·2
2·61 to 3·10 miles ..	2·89	2	28·4	31·5	27·9
3·11 miles or more ..	3·39	2	42·9	31·1	27·8

TABLE XXIX—*Labour turnover in relation to average age.*

Age group.	Coal face workers.			Others underground.		
	Average age.	No of seams.	Mean labour turnover for all underground	Average age.	No. of seams.	Mean labour turnover for all underground
			Per cent.			Per cent.
Under 28 ..	—	—	—	26·3	5	31·7
28 to 31·9 .	30·9	3	39·3	29·6	8	23·3
32 to 35·9 .	33·8	4	26·5	33·5	2	18·4
36 to 39·9 .	38·6	5	23·1	—	—	—
40 or more .	40·7	3	9·6	—	—	—

The relationship of voluntary absenteeism to distance of homes at the individual collieries is shown in Table XL. It will be seen that up to a distance of two miles the absenteeism was fairly steady, whilst at distances greater than two miles it was nearly double as much. The three distant pits which showed the large voluntary absenteeism were not situated in the same neighbourhood. In fact, they were several miles apart.

TABLE XL.—*Voluntary absenteeism in relation to distance of homes from colliery*

Colliery.	Distance of homes from pit in miles.		Percentage of time lost voluntarily by					
			Coal face workers.		Others underground		Mean.	
A (2) .	1·39	1·56	7·0	6·9	2·8	3·7	4·9	5·3
M	1·60		6·8		4·6		5·7	
B	1·68		—		—		—	
Q .	1·78	1·83	—	7·0	—	3·3	—	5·2
J .	1·80		3·9		3·0		3·5	
A (1) D ..	1·81		8·9		3·2		6·1	
A (1), C	1·94		8·2		3·6		5·9	
L	2·13	2·55	12·5	11·8	8·8	7·0	10·7	9·5
P .. .	2·16		—		—		—	
K . .	2·89		11·3		6·0		8·7	
N .	3·00		11·7		6·3		9·0	

(e) *The Proximity of Large Towns.*

It has been mentioned that the collieries investigated were situated within a few miles of two large towns. The Coal Mining Organisation Committee (1915) were informed that absenteeism was always greater at collieries near to large towns than at those situated in rural areas. At the various collieries we ascertained the numbers of men living in different localities, and from these data we have calculated the percentages of men living in, or within easy reach of, these large towns From Table XLI we see that the number varied from 0 to 99 per cent of the men. The collieries with the smallest proportion of men residing in close proximity to towns were those which showed, on the whole, the least absenteeism, but the difference was not marked

Table XLI —*Absenteeism and labour turnover in relation to percentage of men living near large towns*

Colliery	Percentage of men living near large towns.		Per cent of time lost voluntarily.				Per cent of time lost from all causes.				Mean percentage labour turnover	
			Coal face workers		others underground		coal face workers		others underground			
B .	99	95	—	9 8	—	5 3	18 8	16 9	8 4	10 0	26 8	18 7
L .	97		12 5		8 8		21 9		16 0		21 0	
A 2	96		7 0		2 8		13 1		7 3		7 5	
K	93		11 3		6 0		17 2		10·9		28 4	
A (1) C	91		8 2		3 6		13 5		7 5		9 6	
A (1) D	85	77	8 9	10 3	3 2	4 8	18 8	18 0	8 8	9 6	11 8	19 4
N	68		11 7		6 3		17 2		10 4		26·9	
P	25	7	—	5 4	—	3 8	19 4	14 8	14 0	10 1	33·6	26 8
J	2		3 9		3 0		10 1		7·3		20 7	
M	1		6 8		4 6		14 9		9 2		26 0	
Q	0		—		—		14 7		9 9		—	

It has been suggested to us that one explanation of this influence of the proximity to large towns might be the opportunity for the employment of the female members of the colliers' families in the industries of the town. After careful enquiry we have found that in the towns in question there is little opportunity for such employment, and the families living in the towns would be but little better placed in this respect than those in the small mining villages in the neighbourhood. Another and more likely explanation is that in the larger towns there is more distraction to be found in the way of sporting events, excursions and other amusements.

There must be innumerable other causes affecting voluntary absenteeism which we were not able to investigate or obtain evidence about, but one powerful influence was briefly investigated, namely, wage payments. During the 21 months of our chief statistical period the wage rate varied between the extremes of 168·4 and 146·7, and on splitting up the data into three groups and averaging, we observed the following relationships between wages and total absenteeism in the coal face workers at all the collieries combined :—

Mean wage rate.		*Total absenteeism.*
163·1	.. ..	17·3 per cent.
158·0	.. ..	16·4 ,,
147·5	.. ..	16·0 ,,

These figures suggest that the higher the scale of pay the more readily did the men absent themselves. This effect of wage scale is well known in other industries, and again it is illustrated in the present report by comparing the absenteeism of the well-paid coal face workers with that of the less well-paid other underground men, and of the least well-paid surface workers.

6. Absenteeism of Surface Workers.

We were able to obtain information concerning the absenteeism of the surface workers at all of the ten collieries investigated from August, 1924, to April, 1926. For collieries J and M, and again for A (1) and A (2), the information was combined, so the data recorded in Table XLII relate only to eight units. It will be seen that on an average the surface workers lost 7·7 per cent. of working time, as compared with the 17·1 per cent. shown by the coal face workers and the 10·7 per cent. shown by the other underground men. The smaller loss was due partly to the fact that the time lost from accidents was only a half to a quarter as great as that lost by the underground men, but chiefly to the smaller extent of the voluntary absenteeism. It can be seen from Table III that in the pits where complete data were obtained, the coal face men lost 8·8 per cent. of their time voluntarily, and the other underground men, 4·8 per cent., whilst Table XLII shows that the surface men lost only 3·7 per cent. of it. This lower voluntary absenteeism must have been due in part to economic causes, as already suggested.

TABLE XLII.—*Absenteeism of surface workers from various causes.*

Colliery.	No of men.	Percentage of time lost from				Percentage of time lost from all causes by	
		Sickness.	Accidents.	Voluntary causes.	All causes	Coal face workers.	Others underground
Q ..	462	2·1	0·9	2·8	5·8	14·7	9·9
A .	360	3·7	0·5	2·0	6·2	14·8	7·8
B ..	312	1·9	0·3	4·1	6·3	18·8	8·4
J + M	1,278	3·7	0·9	2·9	7·5	12·5	8·2
K .	608	3·3	0·7	3·7	7·7	17·2	10·9
P .	378	4·4	0·6	3·2	8·2	19·4	14·0
N ..	428	3·6	1·1	5·0	9·7	17·2	10·4
L ..	630	4·0	0·9	5·6	10·5	21·9	16·0
	Mean ..	3·3	0·7	3·7	7·7	17·1	10·7

The loss of time from sickness was almost as great for surface workers as for underground men, but it differed in that it showed a considerable seasonal fluctuation. Presumably this was due to the greater exposure of the surface men to the weather. The percentages of time lost in the four summer months (June to September) and the four winter months (December to March) are recorded in Table XLIII, and it will be seen that at every colliery but one the winter sickness was considerably in excess. The average excess, after weighting, came to 30 per cent. Total absenteeism showed an excess of 6·6 per cent., and if due allowance is made for the time lost by sickness and accidents, it appears that distinctly less time was lost by voluntary absenteeism in winter than in summer, the percentages of shifts lost being 3·7 and 4·1 respectively.

TABLE XLIII—*Seasonal variation in absenteeism of surface workers.*

Colliery.	Sickness.		Accidents		All causes.	
	Summer.	Winter.	Summer.	Winter	Summer.	Winter
Q ..	1·8	2·5	0·7	0·9	5·3	6·7
A ..	2·7	4 6	0·6	0·5	6·5	6·7
B ..	1·7	2·4	0·2	0·3	6 7	6·9
J + M	3·2	4·2	0·9	0 9	7 2	8·0
K ..	2·9	4·1	0·8	0·6	8·1	8·1
P ..	3·4	5·7	0·4	0·6	7·4	9·4
N ..	4·1	3·1	1·2	1·1	10·1	10·1
L ..	3·6	4 2	0·7	1·0	10·8	10·5
Weighted mean.	3·03	3·93	0·76	0·79	7·88	8·40

7. Practical Conclusions.

The value of our analysis of the causes of absenteeism depends on the extent to which it is able to suggest feasible remedial measures for the reduction of absenteeism. We do not claim to have investigated more than a fraction of the numerous causes which influence absenteeism, but we think that we have obtained sufficient information to indicate the most hopeful lines on which progress can be made. Our chief conclusions relate to the extraordinary sensitiveness of the miner to his conditions of work and his general environment. Any and every change of condition affects, not only his voluntary absenteeism, but in addition—as we have indicated at length in previous sections (pp. 5 to 42)—the time lost by sickness and accidents as well. Our results suggest that the most valuable method of reducing absenteeism is to improve the conditions of work. We have seen, for instance, that there is probably a certain narrow range of air movement underground which is associated with a minimum of accidents, and that at lower or higher velocities the accident frequency rises rapidly. Our conclusion that accident and sickness rates increase when the air velocity rises above a moderate figure was unexpected, and it is important that further information on the subject should be obtained. Probably the adverse effect of too rapid air currents is due to their tendency to chill the over-heated and perspiring men, who usually are very scantily clad when at work. Almost unavoidable delays occur from time to time (e g , in the provision of tubs), which necessitate the men standing idle for periods which sometimes exceed twenty minutes in duration. Hence they may easily catch a chill, and in addition such delays may cause them to become temporarily more stiff and clumsy in their movements, and thereby to run an increased chance of accident. Even if improved ventilation does cause a slight increase in sickness and accidents, it may be worth while to introduce it, for it tends to reduce the high temperature of the air, and we saw that temperature is associated to a marked extent with absenteeism from sickness and accidents. Also improved ventilation would reduce the risk of explosion in mines rich in gas. In any case, our data show that in many instances the air velocity was much too low, and in several pits it averaged only 18 to 21 feet per minute at the coal face.

In addition to atmospheric conditions, we saw that other conditions such as the distance walked by the men from pit bottom to working place appeared to influence absenteeism greatly, and it is obvious that this distance could be reduced in many cases by an extension of the system of mechanical transport. There are other underground conditions requiring improvement which we did not subject to statistical investigation, and probably the most important of these is illumination. Such improvements are bound to affect the absenteeism of the miner

The effects of improving the conditions above ground may be equally important, for we saw that such conditions greatly influence the large amount of time lost by other causes than notified sickness and accidents. We found that miners living 2½ miles from the colliery showed nearly double the voluntary absenteeism of those living 1½ miles from it, and there can be little doubt that the introduction of an adequate system of housing in the neighbourhood of a colliery would do much to reduce absenteeism and labour turnover. We obtained no information about the effect of pithead baths, but it seems probable that their introduction would make for increased contentment, and would in consequence reduce absenteeism.

It should be realised that, though many of our correlations were highly significant; it is impossible to predict with any accuracy what the absenteeism would be in individual instances, under a given set of conditions. Our results are *average* results, applying to the large body of men working at a number of pits, and treated as a group. Nevertheless our evidence, if considered with reference to the reduction of the average absenteeism in a community by the improvement of working conditions, is just as valuable as if it applied with equal force to individual instances.

Again, it should be realised that the correlation of absenteeism from any cause with some condition such as temperature, though it proves a definite association of two variables with one another, does not necessarily imply *causation*. The increased or decreased absenteeism may not be due directly to the high or low temperature, but be related to it indirectly, in some way not yet identified. Hence, it is important that we should obtain further information.

8. Summary.

The absenteeism of nearly 23,000 miners, working at a group of ten collieries, was studied for periods of 21 months to six years (p. 3). It was found that the total absenteeism of the men varied with the depth of the workings. In coal face workers the time lost at a depth of 650 ft. averaged 13·8 per cent., whilst that at a depth of 2,160 ft. came to 17·0 per cent , or 23 per cent. more. The haulage men and others working underground showed less absenteeism, but a greater variation, for absenteeism in the deepest pits was 46 per cent. greater than in the shallowest pits (p. 4)

Absenteeism from sickness varies greatly with the underground temperature. A rise of 13 deg. F. in the dry bulb temperature was associated with a 63 per cent. increase of sickness in the coal face workers, whilst a rise of 10 deg. was associated with a 74 per cent. increase of sickness in the other underground men. Presumably this influence depends chiefly on the sudden change of temperature experienced by the men on coming to the surface (p. 9).

Absenteeism from sickness is associated with air velocity, for the average time lost by underground workers other than those at the coal face was 85 per cent. greater at a velocity of 260 ft. than at one of 90 ft. This effect of air currents is probably due to the liability of the very lightly clad men to catch chills (p. 11).

Absenteeism from accidents is likewise related to air velocity. Accidents to underground men other than those at the coal face increased steadily at all velocities from 70 ft per minute upwards, and at a velocity of 264 ft. they were 68 per cent. more numerous than at one of 87 ft. (p. 22).

Accident frequency varies greatly with underground temperature, though accident severity shows but little response as the effect is confined to minor accidents. In comparison with the number of minor accidents (causing less than 10 days' disablement) which occurred at the lowest temperatures (64 deg. d.b. and 61 deg. w.b.), those occurring at the highest temperatures (80 deg. d.b. and 71 deg. w.b.) were 4·3 times more numerous. Accidents causing 10 to 19 days' disablement were, however, only 2·0 times more numerous at the highest temperatures, and those causing 20 to 59 days' disablement were 1·5 times more numerous. Major accidents, causing 60 days or more of disablement, were of almost exactly the same frequency at the highest temperatures as at the lowest ones. The probable explanation of this remarkable differential effect of temperature is discussed in detail (pp. 24 to 29).

There is a close correlation ($r = +$ 95) between depth of workings and dry bulb temperature. At depths of 500, 1,500 and 2,500 ft. the mean temperature was 63·6 deg., 76·3 deg and 89·0 deg respectively Hence it follows that the frequency of accidents is highly correlated with depth. Minor accidents (causing less than 10 days' disablement) were four times more numerous at a depth of 2,200 ft than at one of 670 ft , whilst major accidents were unaffected (p 34).

The accident rate is greatly affected by the thickness of the seam. One seam was found to vary in thickness from 44 to 72 in. at six collieries, and the accidents from falls of coal and side were four times more numerous when the seam was at its thickest than when at its thinnest. This effect was just as marked on major accidents as on minor ones (p. 35).

The average output of coal per man at the coal face varied in the proportion of 1 to 2 at different pits, and accident frequency varied with output. At pits where output was 50 per cent. greater than in other pits, the minor accidents (causing less than 10 days' disablement) were three times more numerous, but accidents causing 20 or more days of disablement showed no increase (p. 38).

Accident frequency is related to labour turnover, for minor accidents causing less than 20 days' disablement were three times more numerous at pits where the annual labour turnover was 20 per cent. or more, than at those where it was less than 10 per cent. However, accidents causing over 20 days' disablement were not affected (p. 39).

Accident rates vary considerably with the age of the men, and reach a minimum at the age of 30 to 39. In comparison with this minimum, coal face workers over 60 years of age showed a 41 per cent. excess in frequency rate, and a 100 per cent. excess in severity rate, whilst the other underground men showed smaller increments (p. 40).

Accident frequency varies greatly at different hours of the shift, and in coal face men working at high temperatures it reached a maximum in the last full hour of work but one. In those working at low temperatures it did not reach a maximum till the last full hour (p. 42).

The time lost by " voluntary " absenteeism (i.e., all absenteeism not definitely attributed to sickness and accidents) was found to vary with the distance walked by the men underground, for men who walked 2,800 yds. showed 58 per cent. more absenteeism than the men who walked 1,330 yds. (p 45). It is related to labour turnover, the men at pits with an annual turnover of 27 per cent. showing 24 to 75 per cent. more voluntary absenteeism than those at pits with a turnover of 10 per cent. (p. 46). Again, it is related to the distance of the men's homes from the collieries, men living 2·6 miles away showing 80 per cent. more voluntary absenteeism than those living 1·6 miles away. It is likewise influenced by the proximity of large towns (p. 50)

Surface workers showed less absenteeism from voluntary causes than underground men, but greater seasonal fluctuations in absenteeism from sickness.

In conclusion, we wish to offer our warm thanks to the managements of the collieries visited by us for their kind assistance during our investigations, and for placing their records at our disposal so freely.

REFERENCES.

ANNUAL REPORT OF SECRETARY FOR MINES (1926) · 119.

CHANEY, L. W., AND HANNA, H. S. (1918) . *Bull. No.* 234 *of U.S. Dept. of Labour,* 131

COAL MINING ORGANISATION COMMITTEE (1915) . Minutes of Evidence Cd. 8009. Q 286–8, 1965–6

DAVIES, E (1922) "The Air-Cooling Plant at the Morro Velho Mine, Brazil." *Trans Inst Min Eng* , 63, 326.

KITSON, H. D , AND CAMPBELL, C. (1923) "Relation between Labour Turnover and Industrial Accidents." *Journ. Indust Hyg* , 5, 92.

MINES DEPARTMENT (1926) "The Support of Underground Workings in the South Wales Coalfield." *Paper No.* 6 *of Safety in Mines Res. Board.*

NEWBOLD, E M. (1926) . "A Contribution to the Study of the Human Factor in the Causation of Accidents." *Report No.* 34 *of Indust Fatigue Res. Board.*

ROYAL COMMISSION ON MINES : REPORT OF COMMITTEE ON ACCIDENTS, Etc. (1909). Cd. 4821, 98

REPORT OF ROYAL COMMISSION ON COAL INDUSTRY (1926) : Cmd. 2600. 180 and 191.

VERNON, H. M., BEDFORD, T., AND WARNER, C G. (1926) : "A Physiological Study of the Ventilation and Heating in Certain Factories" *Report No* 35 *of Indust Fatigue Res Board*

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9. Appendix.

We are indebted to Miss Newbold, of the Statistical Department of the Medical Research Council, for advice concerning the working out of our results, and for the following detailed criticism of the correlation coefficients recorded in Tables IV, etc

"It was noted on page 6 that monthly observations were made of absenteeism from sickness, etc , but that though numerous observations of atmospheric conditions were made for different places in each pit, these were taken at a later date and could not be paired either with the monthly or yearly observations of absenteeism Single mean values for each pit (separated in respect of coal face workers and others underground) had to be taken. To make the fullest use of the data, however, the monthly values of absenteeism were not grouped in calculating the correlation coefficients, but used singly, associating each with the single appropriate mean atmospheric value for the pit in question This treatment raises two statistical points which make the estimation of the correlation difficult The first is that with x the unit is a single observation, and with y the unit is the *mean* of a group (each mean being repeated several times) If the groups were random samples of the whole set of observations, then it is well known that the correlations of means would give the same value as the correlations of single observations If, however, there is selection in choosing the groups (as there certainly was, judging by the distinct differences in atmospheric conditions in different pits), and if there exists any correlation between single observations, then the correlation between the *means* of groups will be larger than the correlation between the single observations The correlations used here are between the means of groups in one variable, and single observations of the other variable, so that the values obtained are probably larger than they would be if separate monthly observations of atmospheric conditions could have been used, but smaller than they would be if the single mean values for each pit for the whole period had been used as units for absenteeism as well as for atmospheric conditions

"The second point concerns the value to be attached to the probable error of these correlation coefficients As the number of independent values of atmospheric conditions is smaller than the number of independent values of absenteeism (varying from 10 to 17 in different Tables, according to the number of seams or pits concerned), it follows that the probable error of r found by the ordinary formula, using the number of independent values of absenteeism as the number of observations, is too small. What it actually is cannot be ascertained, except in respect of limiting maximum and minimum values The values given in the tables are the minimum values. The maximum values for the probable errors recorded in Tables IV, VI, VII, XXXVI and XXXVII can be found by multiplying them by $\sqrt{21}$, or 4·58 (21 being the number of occasions when the same mean value for the atmospheric conditions at each seam or pit was used). The true value of the probable error lies between the two extremes.* The maximum value of the probable errors of the correlation coefficients recorded in Tables XIII, XVI and XXIII, is 1·41 (i e., $\sqrt{2}$) times those quoted.

"In spite of these defects, the correlation coefficients recorded in the various tables are of some utility They indicate that in some instances there is little or no correlation , but in many cases when they did show a substantial degree of correlation, further confirmatory evidence was adduced by analysing the data in sub-groups, and finding them to be consistent."

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* It is not likely that the probable errors approach anywhere near to the maxima, for the mean underground atmospheric conditions are very steady from month to month, and show no seasonal variations. (Note by H M V. and T. B.)

Regression Diagrams.

Regression diagrams are useful in order to indicate the relationships of the results obtained at the individual collieries to one another. The straight regression lines drawn through them indicate the best fit, in which the squares of the distances of the observational points from the line reach a minimum value.

Absenteeism from Sickness.—In Fig. 15 the relationship between absenteeism from sickness and temperature is shown (*cf* correlation coefficients in Table IV, p. 8). It will be seen that the correspondence with the regression lines is moderately good.

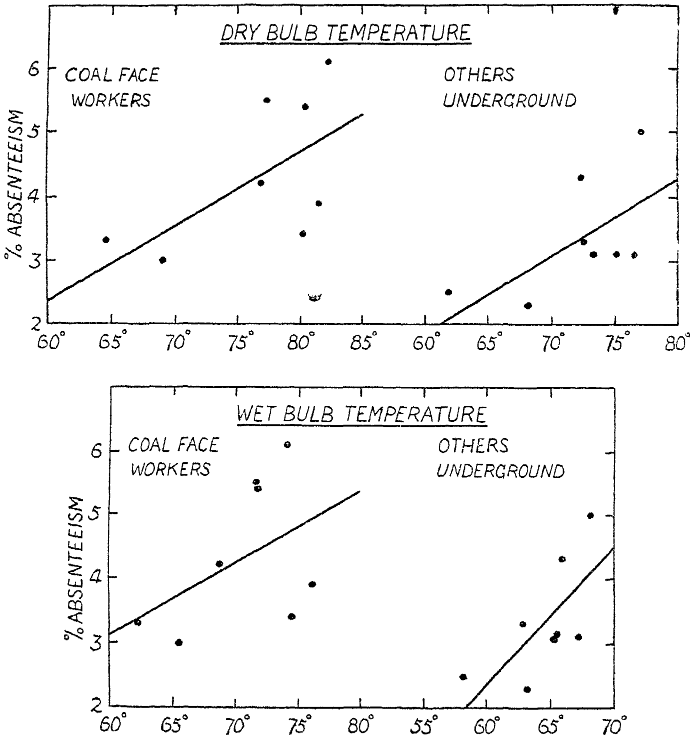

FIG 15. Relationship between sickness and temperature at individual collieries

In Fig. 16 is shown the relationship of sickness absenteeism of the coal face workers with the cooling power of the air (*cf* correlation coefficients in Table VI, p 10). It will be seen that the correspondence with the regression lines is not close.

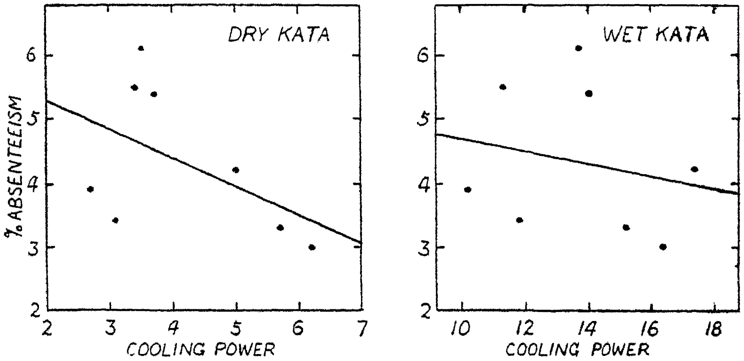

FIG 16. Relationship between sickness of coal face workers and cooling

In Fig 17 is shown the relationship of sickness absenteeism to air velocity (*cf* correlation coefficients in Table VII, p 10). It will be seen that for " others underground " the values agree well with the regression line, and indicate that sickness increases rapidly with rise of air velocity.

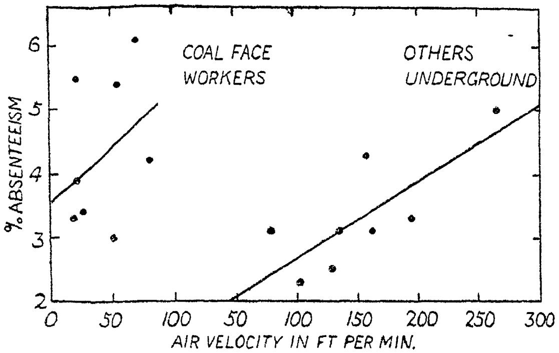

FIG 17 Relationship between sickness and air velocity at individual collieries

In Fig 18 is shown the relationship between sickness absenteeism and the average age of the men at the individual collieries. The corresponding correlation coefficients were + 328 ± ·048 for coal face workers, and + 569 ± 037 for other underground workers (*cf* **3** (*d*)).

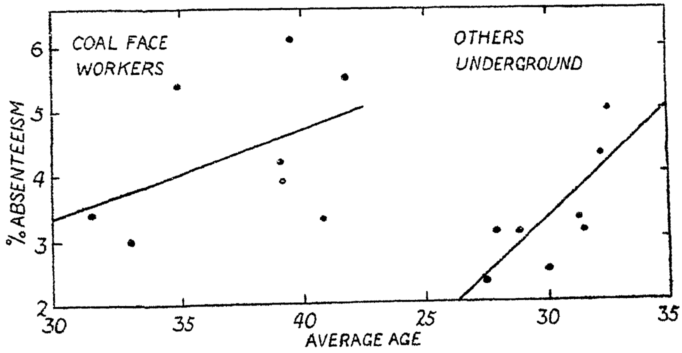

FIG 18 Relationship between sickness and average age of men at individual collieries.

Absenteeism from Accidents—The regression diagrams relating to accidents contain more observations than those relating to sickness, as the number of collieries and seams for which reliable results were obtained was larger For the purpose of diagrammatic representation, each pair of mean values obtained for 1924 and 1925 was averaged The means are plotted in Figs 19 to 21 In Fig 19 is shown the relationship of accident frequency to temperature, and in Fig 20 the relationship of accident frequency to cooling power and to air velocity (*cf* correlation coefficients in Table XIII, p. 19).

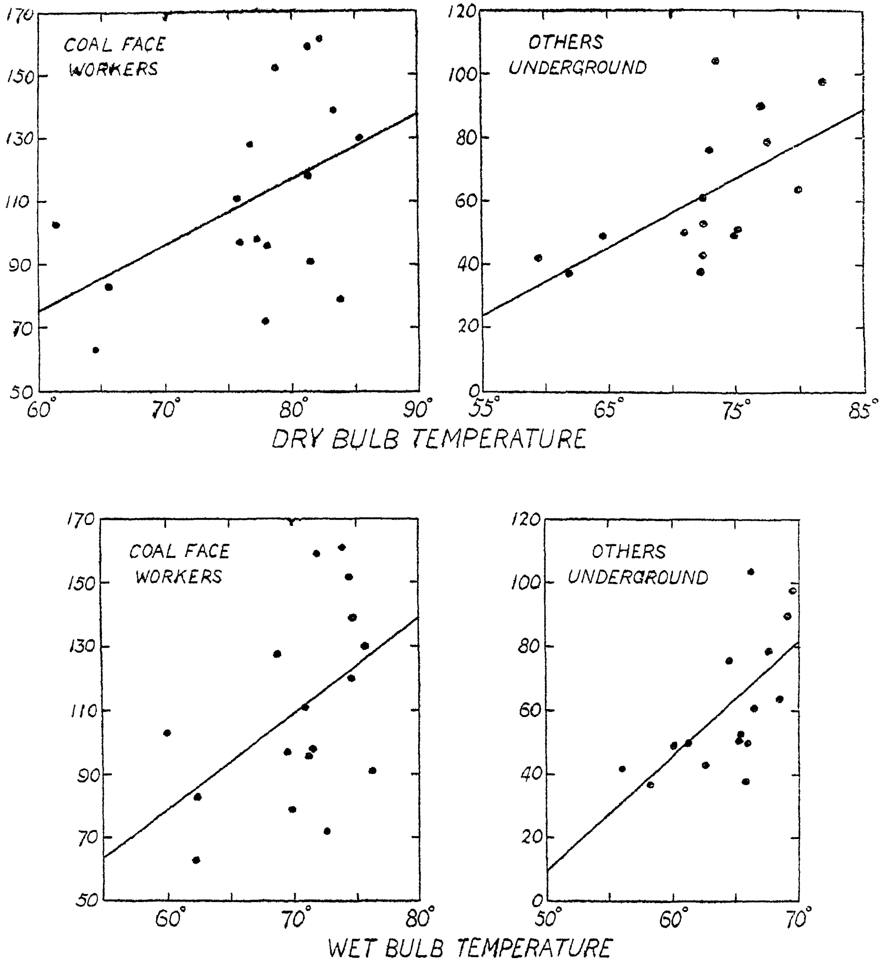

FIG. 19. Accident frequency in relation to temperature.

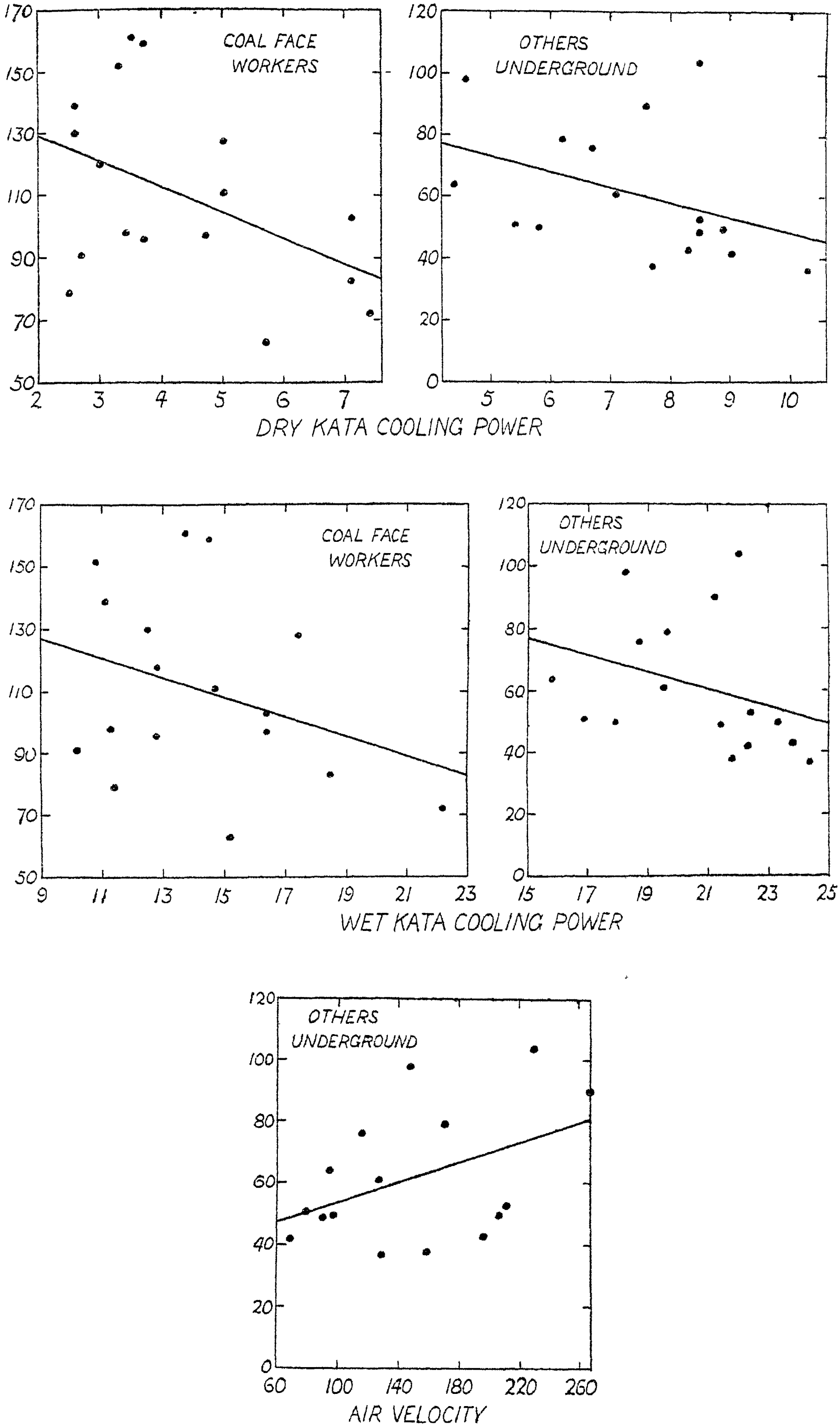

FIG. 20. Accident frequency in relation to various atmospheric conditions.

The relationships of accident severity rates to wet bulb temperature and to air velocity are shown in Fig. 21. It will be seen that, as regards the air velocity diagrams, the values for accident severity of "others underground" agree very well with the regression line, and indicate that the time lost increased rapidly as the velocity increased between the limits of 69 and 264 feet per minute The coal face workers, on the other hand, appeared to suffer a diminishing loss of time as the air velocity increased, but this result is chiefly dependent on the low severity rate observed at pit P. If this result is ignored, the remaining data yield a result which does not disagree with the accident severity rates observed in "others underground," (*cf.* Table XIV, p. 20).

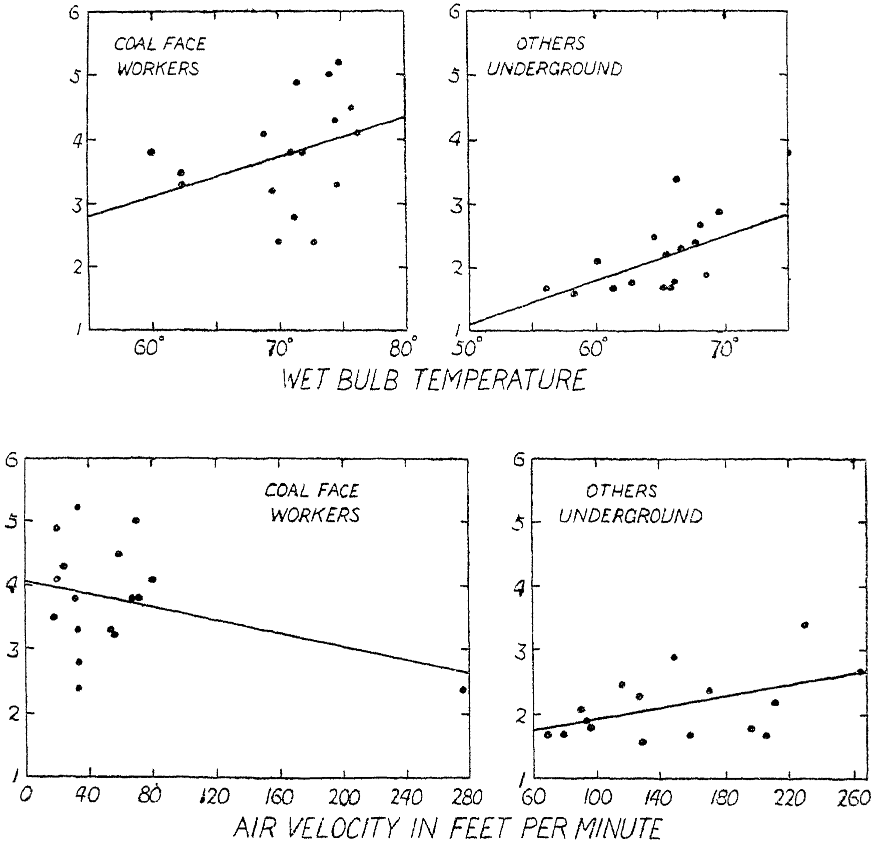

FIG. 21.—Accidents severity in relation to atmospheric conditions.

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SMITH, MAY (1926): Industrial Psychology.—*Article in Encyclopædia Britannica (XIIth Edition).*

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Vernon, H. M (1927): The Elimination of Fatigue caused by Extremes of Temperature, Humidity and Dust—*Rep Internat Ass. for Study of Human Relations and Conditions in Industry.* (Baveno), 1927.

Vernon, H M (1927): Ventilation in relation to Health—*J. State Med.*, **34**, 683.

Vernon, H. M. (1927): The Wet Kata-thermometer as an Index of the Suitability of Atmospheric Conditions for Heavy Work.—*J Indust Hyg*, **9**, 287.

Vernon, H. M., and others (1926): Methods of Investigating Ventilation and its Effects.—*Med. Res. Council Spec Rep. Series No* 100.

Vernon, H. M, and Bedford, T. (1927): The Ventilation and Heating of Factories.—*J Indust. Hyg.*, **9**, 51

Vernon, H. M, and Vernon, M D. (1927): The Physical and Physiological Effects of Radiant Heating by the Panel System.—*Proc. Physiol. Soc., J Physiol.*, **64**, 1.

Vernon, M. D. (1926): On Certain Effects of Long Spells of Repetitive Work.—*Brit. J. Psych.*, **16**, 3.

Warner, E. C., and Hambly, W. D. (1925): An Investigation into the Physiological Basis of the U-tube Manometer Test.—*Guy's Hosp. Rep.*, July, 1925

Weston, H. C. (1927): The Relation between Illumination and Efficiency in Fine Processes, with special reference to the Lighting of Printing Works.—*Illum. Engineer*, **20**, 221.

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Wilson, D. R. (1921): Some Effects of Environment on Efficiency and Safety.—*J. Roy. San. Inst.*, **42**, 3.

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INDUSTRIAL FATIGUE RESEARCH BOARD.

The Comparative Effects of Variety and Uniformity in Work.

By S. WYATT, M.Sc., M.Ed., and J. A. FRASER, M.A., B.Ed.
(assisted by F. G. L. STOCK).

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PREFACE.

Previous investigation conducted for the Board[1] has indicated that in most repetitive processes, even those which are apparently conducted without any break, the operations involved are not in fact repeated again and again with mechanical precision, but that some variety is occasionally introduced, whether this consists in complete cessation of work or in some temporary change in occupation.

It would appear then that under existing conditions the fatigue and monotony that would be caused by strict uniformity are already relieved to some extent either by the conditions under which the work is done or by the action of the operative himself, and the question arises as to what are the optimum conditions for such relief, for it is clear that the degree of variety introduced must be limited by practical requirements

An attempt to gain information on this point has been already made through a preliminary investigation,[2] conducted in 1924 and based on actual observation at a factory supplemented by some experiments under laboratory conditions This showed that, whereas in the laboratory, work-spells in which the same activity was maintained throughout were inferior both in quantity and quality of output to those in which changes of activity were introduced, in the factory, the highest output, measured by earnings, occurred on days of uniform activity, though there were indications that no diminution need necessarily result from occasional, as distinct from frequent, changes in the type of work.

The results obtained, therefore, were, if not contradictory, at least inconclusive, and the Board felt it desirable to initiate further investigation on a more extended scale and in several occupations, in order not only to study the comparative effects of uniformity and variety of work in existing industrial practice, but also to experiment with different degrees of variety, in order to gain some knowledge as to optimal conditions. The results of this investigation, which are embodied in the present report, favour the view that complete uniformity in manual repetitive work is generally less productive and leads to greater irregularity in the rate of working than a reasonable degree of variety, which is also preferred by the workers, though this effect seems to depend partly on the nature of the process and partly on the individual operative. Furthermore, while frequent changes are definitely detrimental to production, there is some evidence that the best conditions are attained when the form of activity is changed after 1½ to 2 hours of unvaried work.

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[1] VERNON H. M and WYATT, S. (1924) On the Extent and Effects of Variety in Repetitive Work. Part A.—*I.F R.B. Report No.* 26

[2] *Ibid.* Part B.

(33074) Wt. 6807/534/499 1000 1/29 Harrow G. 25.

THE COMPARATIVE EFFECTS OF VARIETY AND UNIFORMITY IN WORK.

By S. WYATT, M.Sc., M.Ed. and J. A. FRASER, M.A., B.Ed.
Investigators to the Board,

Assisted by F. G. L. STOCK.

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Introduction.

Previous investigations[1] have shown that, in certain forms of repetitive handwork, the rate of working cannot be maintained at a consistently high level during an unbroken spell of four or five hours, but is retarded and increases in variability about the middle or towards the end of the spell, whilst at the same time voluntary stoppages tend to become more numerous. These features of the work curve have been attributed partly to the inhibiting effects of boredom and fatigue, and partly to the uniformity in posture maintained during work, and have led to the conception that the introduction of short authorised rests or of changes in the form of activity at suitable times within the spell of work, would tend to neutralise most of the objectionable effects, and, by conserving the energy of the operatives, give rise to increased output and greater personal satisfaction.

Rest-pauses have already been the subject of several investigations, and the results obtained have usually confirmed these expectations.[2] The possibilities connected with the introduction of changes in activity have, however, received little attention.

The general results disclosed by previous investigations on the effect of changes in activity may be summarised as follows :

(1) A change in activity is beneficial only when the substituted task is easier than the operation it replaces.[3]

(2) The superiority observed under the varied conditions of work is most marked when the substituted activity is widely different from the one it replaces.[4]

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[1] Reports No. 1, 2, 5, 9, 20, 23, and 32 of the Industrial Fatigue Research Board.

[2] Reports No. 25, 32, 41, and 42 of the Industrial Fatigue Research Board.

[3] WEYGANDT : " Ueber den Einfluss des Arbeitswechsels auf fortlaufende geistige Arbeit." *Psychol. Arbeit.* Vol. II, pp. 118-202.

[4] THORNDIKE : " *Educational Psychology* " Vol III, p. 135. Teachers' College, Columbia University.

(3) Frequent changes in the form of activity are detrimental to output,[1] and long periods of unvaried work are equally unfavourable.[2]

(4) Organised change periods are preferable to irregula interruptions throughout the day.[3]

In addition, numerous experiments have been carried out in the field of education[4] for the purpose of adjusting the length of the lesson period to the age of the child, the fatiguing effect of the subject taught, and the nature of the preceding lesson. These, together with knowledge derived from long and intimate contact with children while at school, have resulted in shorter lesson periods for younger children, in the placing of the more difficult subjects in the early part of the morning period, and in a general recognition of the importance of alternating difficult and easy subjects or subjects which involve different mental and physical processes. In general, it is recognised that, even with older children and university students, a subject such as mathematics should not be continued for more than an hour, while much wider limits are assigned to subjects such as drawing or needlework.

Although educational experiments along these lines have contributed a certain amount of information regarding the most suitable duration for different forms of activity, they do not provide any direct information on the relative effects of uniformity and variety of procedure throughout the day, and consequently are of restricted value so far as industry is concerned. Further, results obtained from children cannot be regarded as directly applicable to adult industrial operatives, and are more suggestive than conclusive.

Procedure Adopted.

A preliminary survey of repetitive conditions in industry showed that in some processes, the operatives were sometimes employed in varied forms of work, while on other occasions the same form of activity was continued throughout the day. Accordingly it seemed advisable to begin the enquiry by a general consideration of existing conditions, whenever these offered facilities for comparing the effects of variety and of uniformity respectively. By this procedure it was hoped to obtain definite suggestions for more specific enquiries. The results presented in the first section of the report refer to different types of repetition work having little in common as regards the number, nature, and duration of changes in the form of work. Since the number of operatives observed in each process also was small, the results must be regarded as illustrations of the effect of specific conditions rather than as affording evidence of a more general nature.

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[1] SCHULZE · "*Zur Ueberbürdungsfrage*" Jena, 1897, p. 20, and *Report No.* 26 *of the Ind. Fat. Res. Board,* p 13.

[2] *Reports Nos.* 26, 32, and 47 of the *Ind Fat. Res. Board.*

[3] MILES AND SKILBECK : *J. Nat. Inst. Ind. Psychol Vol. I, No.* 6, *p.* 236, and "Rest Periods for Industrial Workers," *Research Report No.* 13, *of the Nat. Indust. Conf. Board,* p. 17.

[4] *See,* for instance, ROBERT R. RUSK : "*Experimental Education.*" Longmans, Green & Co., London, 1921, Ch. XIV.

The second part of the report is devoted to the results of experiments conducted for the purpose of determining the effect of changing the form of work at different times throughout the day, and represents an attempt to obtain more definite information on one of the points arising from the preliminary enquiry.

A complete record of output, together with the number, nature, duration, and time of occurrence of stoppages, was obtained in respect of each operative, so that observations were necessarily limited to one or two operatives at a time. Although this method of procedure is slow and exacting, it provides a detailed and continuous record of the behaviour of each worker, discloses the existence of factors which would otherwise be overlooked, and facilitates the accurate interpretation of the results obtained.

Preliminary Investigations.

(A) SOAP WRAPPING

Conditions of work and experiment.—In this process the girls first went to the stores for wrappers and 144 tablets of soap. 72 of these tablets were then wrapped in waxed paper and afterwards in an outer wrapper. The ends of the latter were next gummed and labelled and the completed tablets packed into small cardboard boxes (3 tablets in each box). Up to this point the worker was seated while wrapping and packing, but she now stood at the bench and wrapped the filled boxes in brown paper (4 boxes to each package), sealed and labelled the ends, and placed them in a wooden case. The remaining 72 tablets were then treated in a similar manner, and the wooden case carried to a conveyer some distance away. The operation was thus very varied both as regards activity and posture, but subsequently the girls were moved to a bench where the soap was supplied by a conveyer and only the processes of wrapping and packing into cardboard boxes were performed.

Observations were first made on six girls engaged in performing the varied operations. The time taken to complete each component movement in the complete cycle of operations was noted over a period of five days for each worker; and afterwards observations were made over a similar period when the girls were employed on the more uniform conveyer work. The girls worked on a piece-rate system of payment from 8 till 12 in the morning and from 1 till 5 in the afternoon.

Results obtained.—By comparing the hourly output obtained in the complete operations of inner and outer wrapping and packing into boxes under the two conditions of work, an indication can be obtained of the relative efficiency of the two processes. This is shown in Table I,

Table I.—*Average hourly output on days of uniform and varied activity.*

Worker	A	B	C	D.	E.	F.
Uniform process	194·2	246·0	243·8	223·6	245·5	214·3
Varied process . . .	185·7	240·9	237·3	222·5	230·2	206·9
Per cent. diff. (1)	—4·4	—2·1	—2·7	—0·5	—6·2	—3·5

The results show that in the case of each operative, the uniform method of procedure was somewhat superior to the varied process as far as output is concerned. The average rate of working under the former conditions was 3·2 per cent. quicker than under the latter, and varied from 0·5 to 6·2 per cent. in the case of the different operatives.

Apart from the relative effects of uniformity and variety on output, fluctuations in the rate of working throughout the day also appear to be worthy of consideration. Variations of this type may be measured by the standard deviation of the consecutive short-time observations from their average. The curves given in Fig. 1 show the general trend[2] in the rate of working for each operative under uniform and varied conditions of work.

In three cases (workers A, B, and D) the rate of working under the varied method of procedure was significantly steadier than under the uniform conditions; in another two cases (workers C and E), the differences, although steadier, were not significant, while in the case of worker F the deviations from the average were slightly less when the work was uniform and continuous throughout the day. On the whole, therefore, in this group of workers, the more uniform rate of working appears to be associated with variety in the method of production.

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[1] In this and the following tables, the percentage difference in output is calculated on the basis of the output observed under the uniform method of procedure.

[2] The general trend was obtained by finding the average of every seven consecutive five-minute observations throughout a composite day.

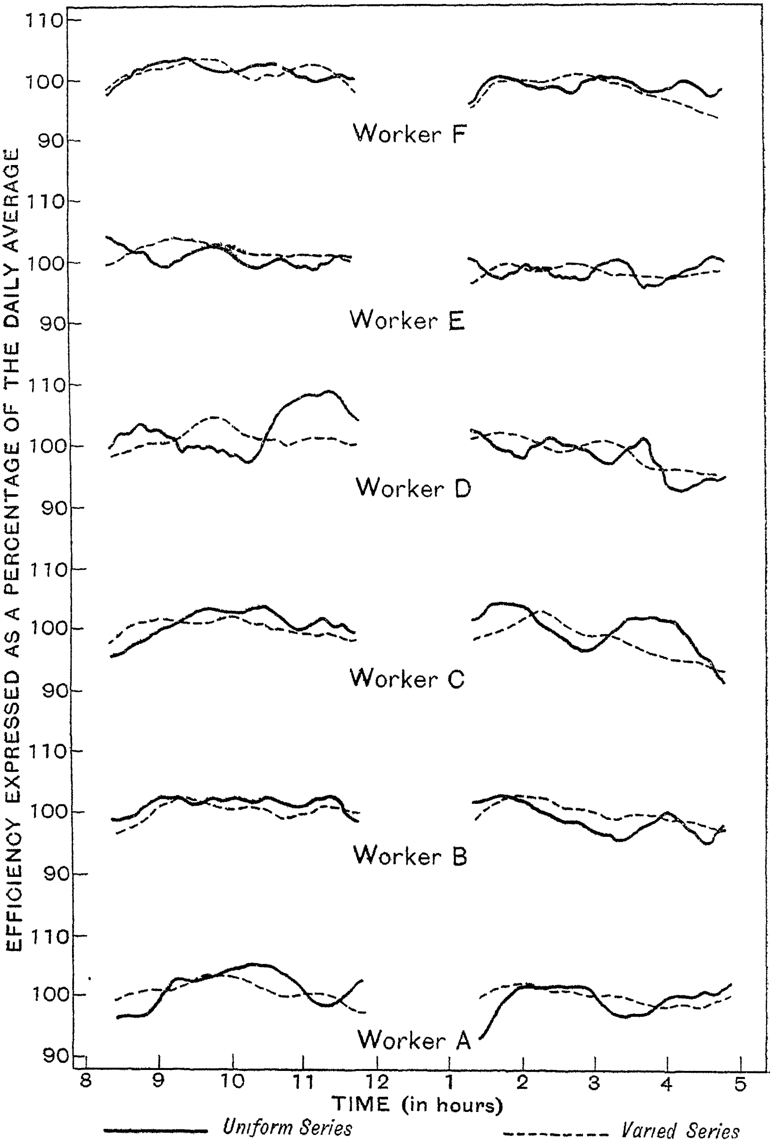
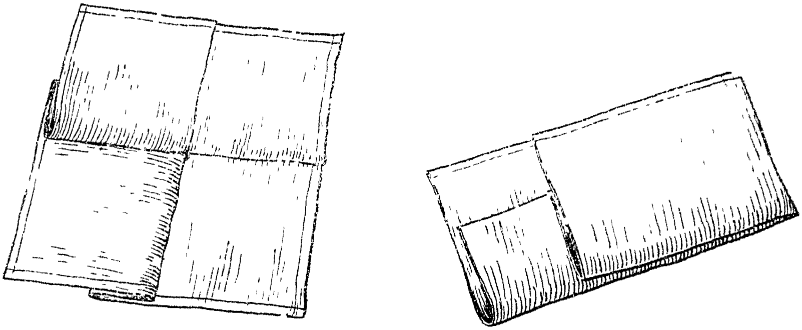


FIG. 1. Comparative rate of working on days of uniform and varied activity. (Soap wrapping.)

(B) HANDKERCHIEF FOLDING.

Conditions of work.—In this factory the handkerchiefs were folded in two different styles, known respectively as the Oblong and French styles. The difference between the folds is illustrated in Fig. 2.

The styles differed considerably in appearance, although the folding of both involved fairly similar movements. The size of the handkerchief square used in the Oblong fold was 18 in., and that used in the French fold was 12 in


French style

Oblong style

FIG. 2. Diagram illustrating (*a*) French style, (*b*) Oblong style of fold.

In this process eight girls were each observed over a period of three weeks. and the time taken to fold a dozen handkerchiefs noted continuously throughout the spell. On some days the Oblong and French styles were folded alternately at approximately hourly intervals, but on others the same style of fold was maintained without change. A comparison can accordingly be made between the rate of working on days of uniform and varied activity.

Observations were limited to the afternoon spell, which extended from 1.15 to 5.30. The operatives were paid on a piece-rate basis, but a premium of 16 per cent. was given on earnings between 15*s*. and 30*s*., and a premium of 25 per cent. on earnings above 30*s*.

Results obtained.—The average hourly output (in dozens) obtained by each worker under the two different methods is given in Table II.[1]

The results show that, in general, there is little to choose between the two methods under consideration. The average output under the varied conditions was only one per cent. greater than in the uniform, and in no case can the difference be regarded as statistically significant.

---

[1] The Oblong style has been used as the basis of comparison.

Table II.—*Average hourly output (in dozens) on days of uniform and varied activity.*

Worker	A.	B	C.	D.	E.	F.	G.	H.
Uniform process . .	27·8	27 5	24·1	26·3	24·9	27·1	22·8	24·6
Varied process . .	27·9	28·0	24·8	26·4	24·5	26·9	23·7	24·9
Per cent. diff. . .	+·4	+1·8	+2 9	+·4	−1·6	−·7	+3·9	+1·2

The curves given in Fig. 3 show the average time taken to complete a unit of output during each quarter-hour period under uniform and varied conditions of work.

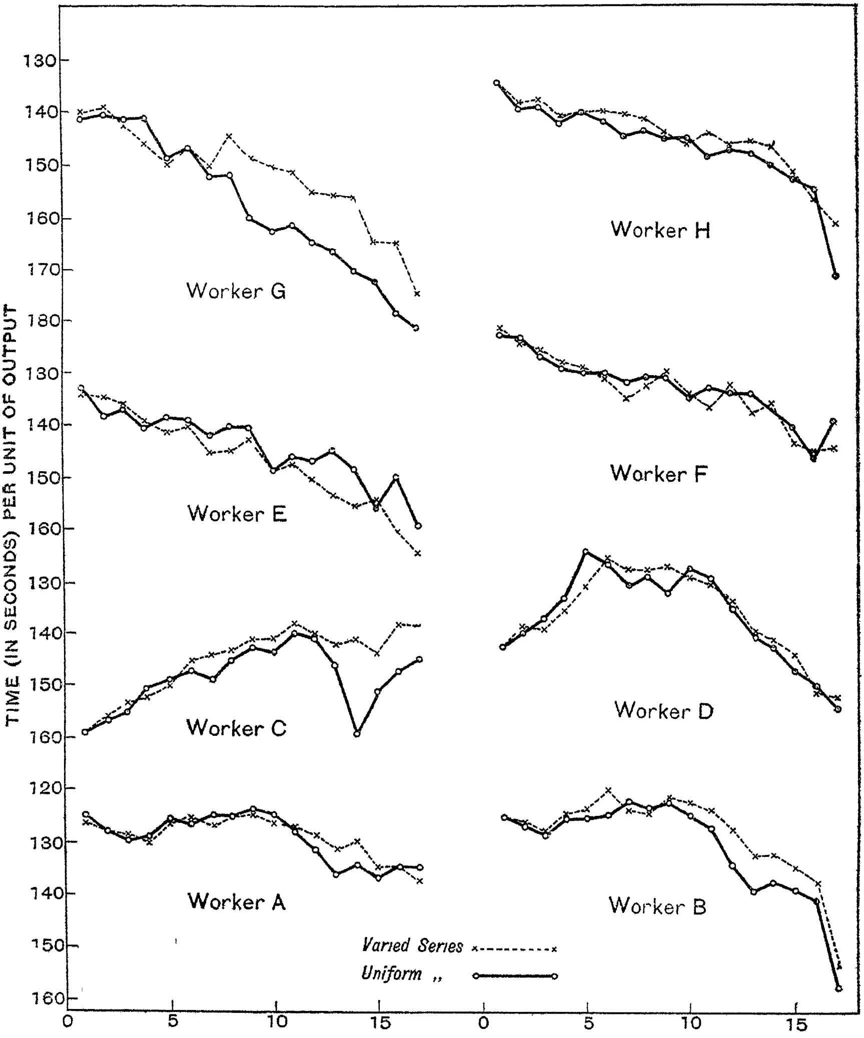


FIG. 3. Comparative rate of working on days of uniform and varied activity. (Handkerchief-folding.)

Although, on the whole, the two curves for each worker are very similar in appearance,[1] those for workers A, B, C and G tended to remain on a higher level towards the end of the spell when the form of activity was changed at approximately hourly intervals. The difference between the deviations from the average for each pair of curves is, however, statistically insignificant.

(c) BICYCLE CHAIN PROCESS.

Conditions of work.—The particular process considered, known as " drifting," represented a typical repetitive operation the same cycle of movements being repeated from ten to fifteen thousand times during the course of a day. In this process the links used in the manufacture of bicycle-chains were placed on steel shafts which were slightly wider in the middle than at the ends. The links were forced along the shafts by mechanical pressure and any irregularities in the shape or size of the holes were in consequence removed. The essential features of the process will become clear on reference to Fig. 4.

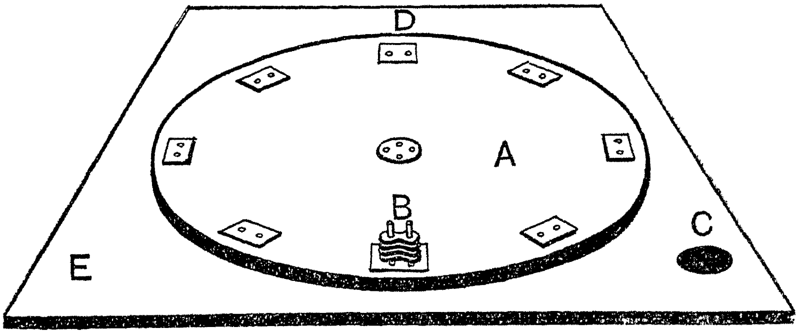


FIG. 4. Diagram of mechanism used in bicycle chain assembling.

The operative was seated in front of the rotating disc A, which moved through one-eighth of a circle every 1·64 seconds. During that time she took out the steel shafts B on which were four links, and flicked off two through the hole C. The operative then picked up two links with the left hand from a supply at E, placed them on the shafts held in the right hand, and inserted the shafts into the two holes on the disc. A mechanical punch at D pressed the shafts through the links, thereby freeing the fast links and forcing the loose links on to the wider parts of the shafts, so that the shafts always contained two fast and two loose links. Theoretically the operative was expected to keep pace with the disc, but in practice she was usually unable to do so, and many shafts were allowed to pass untouched.

---

[1] The striking similarity between each pair of curves, representing different work-periods, suggests that each individual has a characteristic output curve.

Four girls were observed in this operation and their hourly output measured at hourly intervals over a period of three weeks. During another two weeks arrangements were made for the girls to be employed on a stacking operation[1] during the first half of the morning and afternoon spells, and to return to their usual occupation for the remainder of the time. By this means it was possible to compare the output obtained during the second half of each spell under the latter arrangement with that produced in a similar period when the same kind of activity was continued throughout the day.

The hours of work in this process were from 8.0 to 5.30 with a break from 10.0 to 10.15 and another from 12.45 to 1.45 for dinner. The operatives were paid on a piece-rate basis.

Results obtained.—The average hourly output obtained from each worker when performing the usual operations on days of uniform and varied activity is given in Table III. The results are expressed as a percentage of the possible output.

Table III.—*Average hourly efficiency at corresponding times on days of uniform and varied activity.*

Worker.	A.	B.	C.	D.
Uniform process ..	77·4	61·4	61·5	62·8
Varied process ..	79·4	64·2	64·6	64·3
Per cent. diff. ..	+2·6	+4·6	+5·0	+2·4

In this process, therefore, the results appear to be in favour of the varied method of procedure.

The output curves obtained under the two conditions of work are given in Fig. 5.

These show that when the same kind of activity was continued throughout the day, an appreciable decrease in efficiency occurred towards the end of the spell, but that when the girls were employed on a different task in the first half of the spell, the subsequent decrease in efficiency was less.

It is interesting to note that the percentage improvement on the days of varied work progressively increased as the end

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[1] In the stacking operation the girls placed links on two long parallel shafts in readiness for another operation.

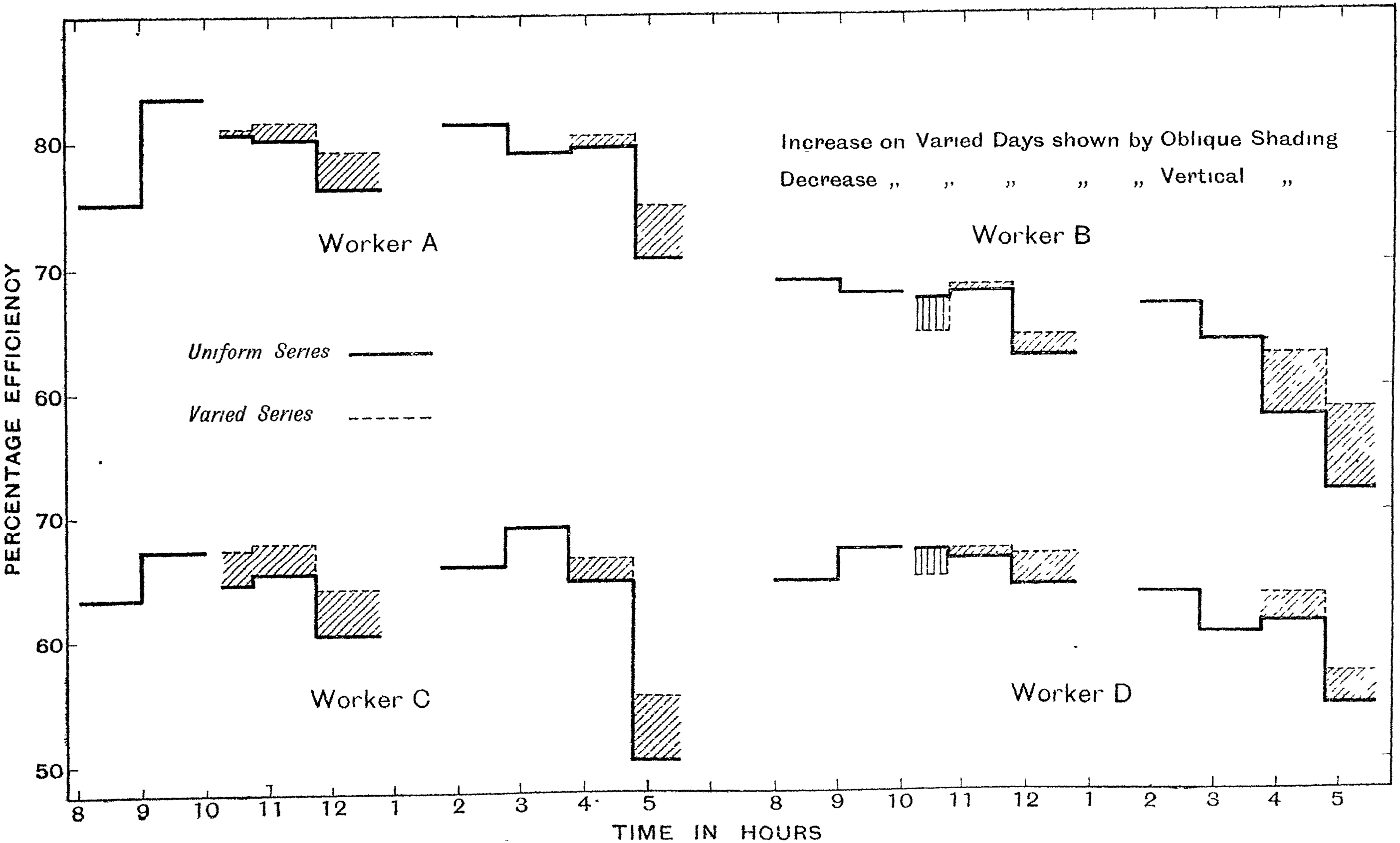

FIG. 5. Hourly variations in efficiency on days of uniform and varied activities.

of the spell was approached, and was greater in the afternoon than in the morning spell of work. This feature of the results is shown numerically in Table IV.

Table IV.—*Percentage gain in efficiency during the latter half of the spell on days of varied activity.*

Worker	10.15 to 10.45	10 45 to 11.45	11 45 to 12.45	10.15 to 12.45	3.45 to 4.45	4.45 to 5.30	3.45 to 5.30
A .	0·37	1·62	3·67	2·19	1·13	5·95	3·20
B .	−4·01	0·59	2 55	0·45	8·63	12·52	10·30
C ..	4·32	3·66	5·76	4·63	2·47	10·14	5·76
D ..	−3·27	1·05	4·05	1·39	3·76	4·19	3·94
Avg ..	−0·65	1·73	4·01	2·16	4·00	8·20	5·80

Experiments on the Optimum Duration of Unvaried Activity.

The results obtained in the preliminary enquiries already described suggest two distinct problems for investigation, viz. :—

(i) The determination of the optimum duration of one form of activity before changing to another.

(ii) The determination of the most suitable type of work for the alternating processes.

Under existing industrial conditions it will probably be difficult to find the necessary conditions and facilities for investigation, and the most desirable form of procedure may have to be modified in consequence. An attempt, however, has been made to determine the optimum duration of activity for particular kinds of work, and the results obtained are considered in the present section.

(A) TOBACCO-WEIGHING.

Conditions of work.—In this process the operatives worked in pairs. One of the operatives (the weigher) cut off and weighed one ounce quantities from a large roll of twist. These were then passed to the second operative to be wrapped. The wrapper could barely keep pace with the weigher, so that a certain amount of unwrapped tobacco tended to accumulate throughout the spell of work, which was usually wrapped by both operatives during the last 10 or 15 minutes of the spell.

The weigher and wrapper generally changed operations at irregular intervals within the spell of work, but sometimes the same process was continued throughout the day. Each operative was accordingly experienced in both the weighing and wrapping processes.

The hours of work were from 8.0 to 12.30 and from 1.30 to 5.0 with a break of 10 to 15 minutes at 9.30 for refreshment. A time-rate system of payment was in vogue.

Procedure adopted.—It was decided to ascertain the relative effects of changing the form of activity at definite times within the spell of work. For this purpose a scheme was adopted, enabling a comparison to be made of the effects of two changes, one change, and no change in the form of activity within the spell of work. This scheme may be expressed as follows, (Wg. and Wr. indicating the periods spent in weighing and in wrapping respectively) :—

First series.

Worker		8.0 to 9.30	9.45 to 11.0	11.0 to 12.30	1.30 to 2.30	2.30 to 3.30	3.30 to 4.30	Days observed.
A	..	Wg.	Wr.	Wg.	Wg.	Wr.	Wg.	2
B	..	Wr.	Wg.	Wr.	Wr.	Wg.	Wr.	2
A	..	Wr.	Wg.	Wr.	Wr.	Wg.	Wr.	2
B	..	Wg.	Wr.	Wg.	Wg.	Wr.	Wg.	2

Second series.

Worker		8.0 to 9.30	9.45 to 12.30	1.30 to 3.0	3.0 to 4.30	Days observed.
A	..	Wg.	Wr	Wg	Wr.	2
B	..	Wr.	Wg.	Wr.	Wg.	2
A	..	Wr.	Wg.	Wr.	Wg.	2
B	..	Wg.	Wr.	Wg.	Wr.	2

Third series.

Worker.			Days observed.
A	..	Weighing all day	4
B	..	Wrapping all day	4
A	..	Wrapping all day	4
B	..	Weighing all day	4

Usually two pairs, though sometimes only one pair of operatives were observed at a time, and a record was kept of the number of ounces weighed in consecutive five-minute periods throughout the day. The nature, duration, and time of occurrence of all stoppages were also noted.

Results obtained.—The percentage increase or decrease (—) in output obtained by introducing changes in the form of activity at specified times within the spell of work is given in Tables V. and VI.

Table V.—*Percentage increase or decrease* (—) *in output*[1] *obtained when the form of work was changed twice within the spell.*

Worker	8.0 to 9.30	9.45 to 11.0	11.0 to 12.30	a.m. Avg.	1.30 to 2.30	2.30 to 3.30	3 30 to 4 30	p.m. Avg.	Day Avg.
A .	15·6	17·4	27·3	20·3	7·9	7·3	3·6	6·3	14·5
B ..	−4·5	10·4	27·1	11·0	24·8	0·8	−1·9	7 9	9·7
C ..	14·0	10·4	14·2	13·0	3·1	18·3	18·5	13·3	13·1
D ..	3·0	4·2	14·2	7·3	1·3	14·3	10·0	8·5	7·8
E ..	25·5	28·5	12·5	21·8	21·2	27·2	37·5	28·6	24·6
F ..	16·9	12·6	21·7	17·3	8·6	8·6	11·7	9·6	14·1
G .	1·5	3·2	5·6	3·4	6·6	9·2	5·8	7·2	5·0
H .	9·7	8·1	39·9	19·9	10·1	11·5	35·3	19·0	19·5
I ..	16·8	3·1	22·9	14·9	25·8	30·1	17·8	24·6	18·9
J ..	−3·8	15·4	17·8	9·5	−4·0	16·7	23·0	11·9	10·5
Avg.	9·5	11·3	20·3	13·8	10·5	14·4	16·1	13·7	13·8

[1] i.e. The difference between the output obtained at corresponding times on days of varied and uniform activity expressed as a percentage of the latter.

Table VI.—*Percentage increase or decrease* (—) *in output obtained when the form of work was changed once within the spell.*

Worker.	8.0 to 9.30	9.45 to 12.30	a m. Avg.	1.30 to 3.0	3.0 to 4.30	p.m. Avg.	Day Avg.
A	7·2	5·8	6·3	8·4	5·1	6·7	6·5
B	−0·4	3·6	2·2	29·6	2 3	15·9	7·9
C	10·0	8·9	9·3	12·1	10·3	11·2	10·1
D	−0·9	4·8	2·8	13·9	13·1	13·5	7·2
E	8·5	1·8	4·2	36·4	10 6	23·5	12·2
F	15·1	6·9	9·8	14·6	11·9	13·2	11·2
G	4·6	10·6	8·5	8·8	11·2	10·0	9·1
H	9·4	16·5	14·0	13·5	20·2	16·9	15·2
I	18·1	18·6	18 4	17·3	25·7	21·5	19·7
J	8·3	18·2	14·7	3·9	18·0	11·0	13·2
Avg. ..	8·0	9·6	9·0	15·8	12·8	14·3	11·2

The results show that when the form of work was changed at specified times within the spell, the output was appreciably higher than that obtained on days of uniform activity. The average increase amounted to 13·8 per cent. when two changes were introduced within the spell, and to 11·2 per cent. when only one change was allowed. The increase was not restricted to any particular part of the spell, but the amount and time of occurrence varied with different workers. In some cases the superiority was most marked about the middle of the spell (*cf.* workers D, G, and I in the afternoon period, Table V), while in others the greatest increase occurred in the latter part of the spell (*cf.* workers H and J) Individual differences in response to the varied conditions of work were very marked, and the increase in daily output varied from 5 to nearly 25 per cent. It is also interesting to note that the output during the first part of the morning spell (8 0—9 30) was generally higher on the days of varied work.

The detailed variations in the rate of working produced by the different conditions are shown in Fig. 6. The curves represent the combined results obtained from the 10 workers.

It is interesting to note that on the days of unvaried activity, the output at the beginning and end of the spell was much lower than on the days of varied work.

(B) CIGARETTE-MAKING.

Conditions of work.—The operatives observed in this process were engaged in making cigarettes by hand. Each operative was provided with a supply of tobacco from which a small quantity was taken and rolled before being inserted into the cylindrical cigarette-paper. The protruding ends of the tobacco were afterwards cut off with a pair of scissors.

The operatives were paid on a piece-rate basis and the hours of work were from 8 0 to 12 30 and from 1 30 to 5 0. A break of 10 to 15 minutes was allowed at 9 30 a.m. for refreshment.

Procedure adopted.—In this process the operatives adopted the procedure of making from 50 to 250 cigarettes and afterwards cutting off the ends. Formerly, however, the ends were cut by an assistant, so that the operatives were familiar with both the varied and uniform method of procedure. It was decided to try the effect of changing the form of work at different times during the day, and the following scheme was adopted for this purpose.

Monday: Making and cutting alternately according to the worker's inclination.[1] (Series 1.)
Tuesday: Making for one hour, then cutting. (Series 2.)
Wednesday: Making for 1½ hours, then cutting. (Series 3.)
Thursday: Making for three hours, then cutting. (Series 4.)
Friday: Making all day. (Series 5.)

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[1] i.e. From 50 to 250 cigarette-papers would first be filled with tobacco after which the ends would be cut off. The time occupied by the making process was about three times that of the cutting operation.

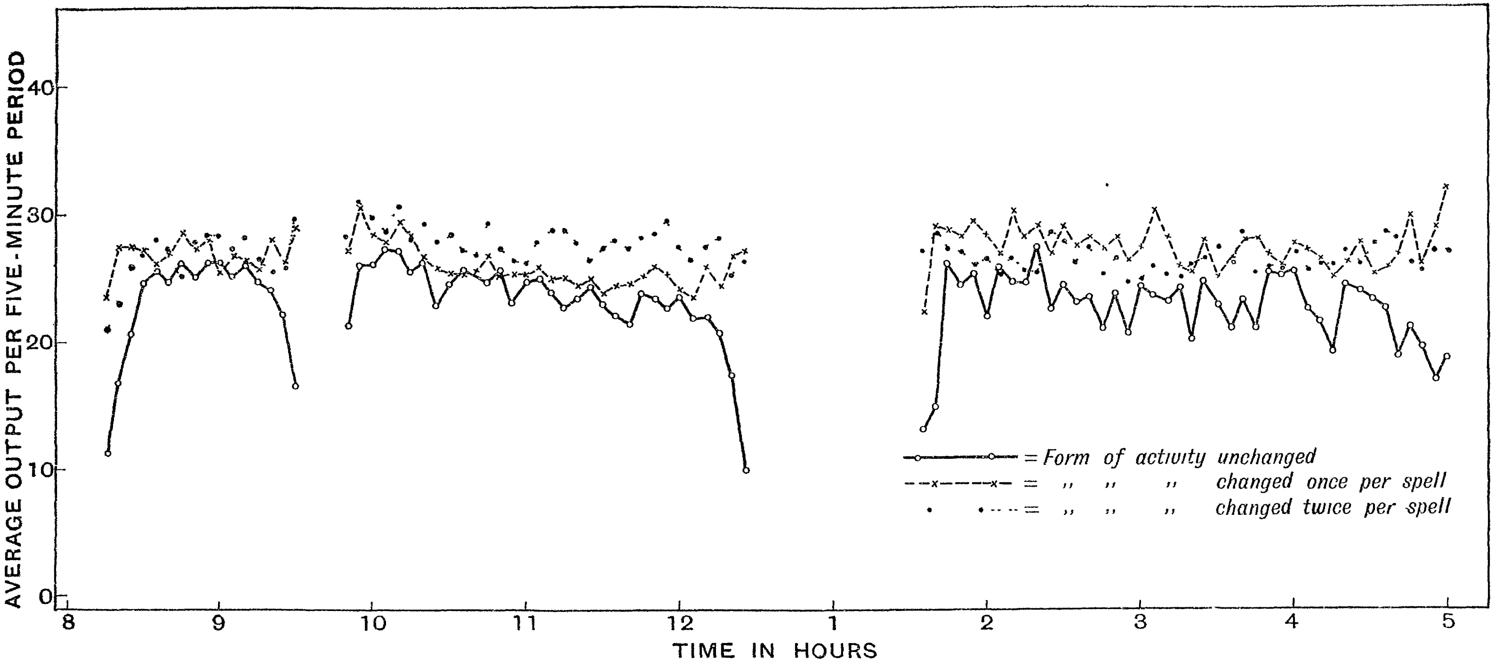

FIG. 6. Variations in the rate of working produced when the form of activity is changed at different times within the spell of work. (Tobacco-weighing.)

Ten operatives were employed in this manner and afterwards the order was reversed and another ten observed. A record was kept of the number of cigarettes made in consecutive five-minute periods and the nature, duration, and time of occurrence of all stoppages were also noted. Since only two operatives could be observed at a time, the total duration of the experiment was 10 weeks.

Results obtained.—The average number of cigarettes made per hour by each operative under the different arrangements is given in Table VII.

Table VII.—*Average number of cigarettes completed per hour under the different experimental conditions.*

Worker.	Series 1	Series 2	Series 3	Series 4.	Series 5.
A	230·2	217·6	223·5	208·2	202·8
B	236·5	242·0	242·7	215·4	212·7
C	226·2	223·8	229·4	217·4	204·6
D	244·2	276·3	281·3	269·3	258·0
E	237·3	241·0	250·6	244·5	226·6
F	216·8	240·9	237·3	215·3	200·1
G	250·5	254·6	252·0	231·2	237·0
H	245·7	255·1	241·3	215·3	227·8
I	251·0	286·5	284·5	261·2	—
J	300·3	312·0	309·1	292·8	—
K	260·3	278·1	288·0	270·5	246·8
L	228·0	227·1	226·4	226·3	228·8
M	203·3	214·3	216·5	205·6	204·8
N	263·9	272·0	279·8	261·9	264·4
O	222·8	217·2	237·1	227·9	204·7
P	211·1	224·9	222·7	213·6	188·7
Q	200·1	201·2	202·1	191·0	178·7
R	209·7	229·3	220·9	212·2	195·9
S	209·4	240·7	242·5	228·9	213·8
T	222·3	235·3	233·1	231·7	237·4
Avg	233·5	244·5	246·0	232·0	218·5

The results show that the highest output was obtained when the making operation of 1 or 1½ hours was alternated throughout the day by cutting periods of approximately 20 or 30 minutes. An average decrease of 5·7 per cent in output was observed when the duration of the cutting period was extended to 3 hours, while a still greater reduction (11·2 per cent.) [1] occurred when this process was continued throughout the day. When the operatives changed from making to cutting according to their inclinations their average output was still 5·1 per cent. below that of the best series. In the uncontrolled method of procedure the duration of the making process varied from 15 minutes to 2 hours in the case of different operatives, while the average duration was approximately an hour.

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[1] This value is probably a little too high, because of the exclusion of the results of workers I and J (the quickest workers) from the average. It was not possible to observe these workers on the day in question.

All the operatives had been engaged in making cigarettes for several years, and appeared anxious to earn as much as possible. They gave the impression of being unusually industrious and serious-minded, and the number of voluntary stoppages was almost negligible. With the exception of workers L and T, all the operatives stated that the unvaried form of work was unpleasant, and was either boring or tiring to the shoulders and arms Such expressions as "The day seems doubly long" and "Making all day almost puts me out" were fairly typical of the remarks received. Generally speaking, the operatives expressed a preference for their own methods of work, but stated that if a regular system were to be adopted, they would prefer to work for an hour before changing to the cutting process.

The variations in the rate of working produced by the different experimental conditions are shown in Fig. 7. Each curve indicates the output produced in consecutive five-minute periods throughout the day, expressed as a percentage of the average output on the days of continuous unvaried activity. The depressions in the curves observed in the early part of the morning spell were due to interruptions caused by one or more of the operatives taking lunch, which occurred at slightly different times on different days.[1]

Considering first the curve obtained on the days of uniform activity, it will be seen that it is on a lower level, and somewhat different in form, from those obtained under the other arrangements of work. In spite of the recuperative effects of the lunch interval at 9.30, a notable drop in output is shown between 10.30 and 11.30 in the morning spell. In the afternoon spell, output began to decrease after work had been in progress for about an hour, and, apart from temporary fluctuations, remained low until the final spurt in the last half-hour of work.

When the workers knew that the form of work would be changed after three hours of uniform activity, a somewhat different type of output curve was obtained. In the first place, the output following the luncheon interval was higher and free from the depression observed on the days of uniform activity, a feature of some interest, since it might be expected that the first three hours of work would yield approximately similar curves in both cases. The afternoon curve is similar in tendency to the one previously described, but is on a higher level and has a more pronounced final spurt.

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[1] The results obtained in Series 1 have not been included in Fig. 6 because a reliable composite curve could not be obtained.

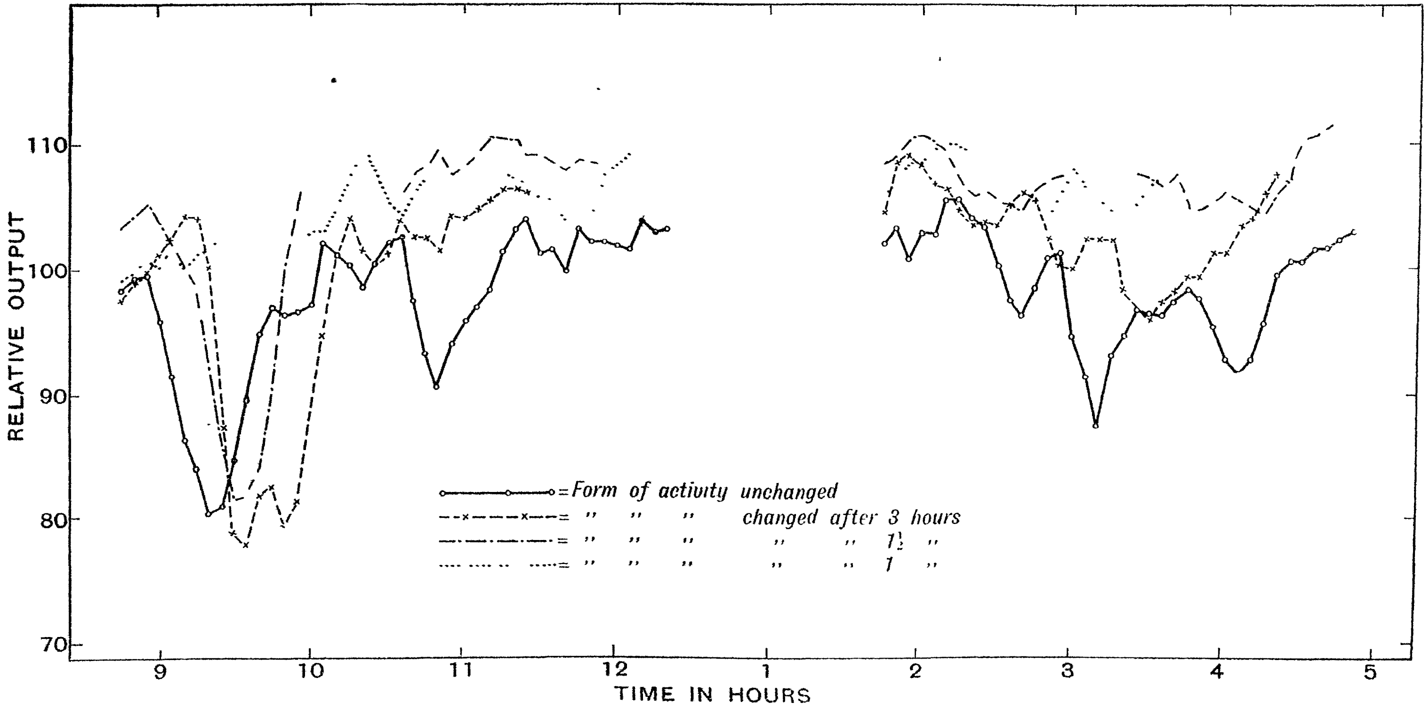

FIG. 7. Variations in the rate of working produced when the form of activity is changed at different times within the spell of work. (Cigarette-making.)

When the change occurred at the end of 1½ hours the beneficial effects were still more marked. The output in the latter half of the morning spell was the highest recorded in any of the experimental series, and was also high in the initial and final stages of the afternoon spell. Although in the latter spell there was a reduction in output in the intervening period the extent of the decrease was very much less than in the two previous cases. Somewhat similar tendencies were noticeable when the same form of activity was never continued for more than an hour, and the output curve approached more closely to a horizontal straight line.

The operatives were unanimous in the opinion that the cutting operation when continued for long periods was very tiring. As a result, accuracy of movement was impaired and the ends of the cigarette-paper were sometimes cut away together with the surplus tobacco. Making cigarettes, on the other hand, was said to be comparatively pleasant and was more conducive to boredom than to fatigue. Additional illustrations of the principles involved in these expressions of opinion will be given in the next section.

(c) ASSEMBLING CARTRIDGE CASES.

Conditions of work.—The operatives observed in this enquiry were employed in assembling the parts of a special kind of sporting cartridge The complete operation involved three distinct processes done successively, viz. :—

(i) *Stacking.*—For this process the operative was supplied with a box containing cylindrical cardboard cases on which the distinguishing characteristics of the product were printed. These cases were taken from the box and stacked on a shallow tray in such a manner that the printed matter on the cases always pointed in the same direction. The upper surface of the stacked cases accordingly appeared as a number of juxtaposed circular rims.

(ii) *Assembling.*—The operative now took a small metal lining from one box and a wad from another. The wad was placed inside the lining and the two together were then inserted into the top of one of the cases on the tray. Each of the cases was treated in a similar manner until the entire tray was finished.

(iii) *Pushing down wads.*—By means of a metal rod the wads and linings were now pushed down the cases until they rested on the base of the tray.

The operatives were paid according to the number of trays completed and the hours of work were from 8.0 to 12.30 and from 1.30 to 5.30.

Procedure adopted.—The operatives employed on this operation usually worked with trays which held approximately 750 cases. In order to ascertain the effect of extending the duration of each of the component activities, experiments were tried also with trays capable of holding 1,000 and 1,250 cases respectively. Detailed observations were accordingly made on each of four operatives for a period of 7 days when working with the usual size of tray, and afterwards for similar periods when using the larger trays. The observations were continuous throughout the day, and detailed records of the performance of each operative were obtained.

Results obtained.—The relative output, based upon the time taken to complete 100 cases in the three component processes under the different conditions of work is given in Table VIII.

Table VIII.—*Relative output in each of the component operations.*

Process.	Tray capacity.	Worker A	Worker B	Worker C.	Worker D.
Stacking ..	750	92·5	77·8	96·7	78·1
	1,000	98·8	78·8	104·9	93·1
	1,250	102·2	82·7	112·2	94·6
Assembling	750	27·2	28·6	27·7	26·6
	1,000	28·1	28·8	31·2	29·0
	1,250	28·0	30·9	33·1	28·1
Pushing down wads	750	219	211	199	179
	1,000	228	221	222	196
	1,250	186	223	213	191

It will be seen that, in the stacking process, output increased as the size of the tray increased. In the assembling operation the same tendency was observed except in the case of the largest tray for workers A and D. When pushing down wads, however, the highest output was observed in connection with the tray of medium size.

The operatives engaged in this process appeared to work reasonably well in the morning spell, but to relax more than was necessary in the afternoon spell, and they were undoubtedly restricting output to a certain number of trays per day. Since this behaviour may have had an effect upon the results obtained, it was thought advisable to induce them to work at maximum speed while performing each of the component operations. The purpose of the experiment was explained to them together with the promise of a monetary reward. As a result they willingly offered to submit to the experiment, and the time taken to complete each component operation when working as quickly as possible was noted at specified times within the spell of work.

Only one operation was observed in any single spell, and results were obtained from trays capable of holding 750, 1,000, 1,250, and 1,500 cases respectively. The complete experimental series was repeated after an interval of a month, and the relative output obtained under the different conditions is given in Table IX.

Table IX.—*Relative output in each of the component operations when working at maximum speed.*

Process.	Tray capacity.	Worker A.	Worker B.	Worker C	Worker D.
Stacking ..	750	132	105	124	103
	1,000	148	113	131	115
	1,250	152	115	135	121
	1,500	154	122	134	122
Assembling	750	39·3	36·7	33·7	32·9
	1,000	39·4	41·5	38·7	33·9
	1,250	39·9	39·6	36·9	36·2
	1,500	34·7	34·0	32·8	31·5
Pushing down wads.	750	243	226	219	210
	1,000	251	234	229	245
	1,250	248	228	230	214
	1,500	223	223	218	196

In this series the stacking process still shows that with increase in the size of the tray there is an increase in output; but in the assembling operation the maximum output was obtained with trays of 1,000 and 1,250 capacity. A tray capable of holding 1,000 cases appears the most suitable when pushing down wads. Evidently the optimum duration for each of the component operations depends upon the nature of the activities involved.

Discussion of Results.

Subject to the limitations imposed by the small number of workers observed in each group and the limited facilities for investigation, the preceding results show that when the form of work is changed at specified times within the spell, output is usually increased and a steadier rate of working maintained. The beneficial effects appear to depend upon certain elements in the conditions of work, viz. :—

(1) The nature of the alternating activities.
(2) The frequency of the change periods.
(3) The type of work.

Nature of the Alternating Periods.

The most favourable results produced by changing the form of work were obtained in the bicycle-chain process, tobacco-weighing, and cigarette-making. In each of these operations the alternating form of activity involved a change from one form of work to something very different, it seems highly probable that the dissimilarity between the alternating processes was largely responsible for the increased output observed on the days of varied work. In the handkerchief folding process, although the form of work was changed at approximately hourly intervals, there was no appreciable difference between the results obtained under the uniform and varied conditions of work, and the similarity in question was probably due to the high degree of resemblance in the essential movements (folding and smoothing) involved. At the same time the opinions of the operatives suggested that the varied activities were more satisfying than the results indicate, since they were unanimous and emphatic in their preference for the varied method of folding. In general, therefore, it appears that the extent of the difference involved in changing from one form of activity to another may be a factor of considerable importance.

Frequency of the Change Period.

Generally speaking, the most favourable results provided by the present investigation were obtained when changes in the form of activity were introduced after work had been in progress for 1½ or 2 hours. In the soap-wrapping process, however, although the successive operations on the varied days were widely different from each other and involved numerous changes in posture, the output was lower than on the days of uniform procedure The longest time devoted to any single continuous operation under the varied conditions of work was never greater than 15 minutes, while in many cases only a few seconds elapsed before a change occurred. Under such conditions the swing of work was frequently interrupted, and the maximum rate of working seldom attained.

The unfavourable effects of too many changes in the form of activity observed in this instance are similar to those noted in a previous report.[1] A somewhat similar explanation would also account for the slower rate of working observed when stacking the smaller trays in the cartridge assembling operation.

It seems reasonable to infer, therefore, that changes in the form of work must not be too numerous if a high degree of efficiency is desired.

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[1] Report No. 26 of the Industrial Fatigue Research Board, p. 13.

Type of Work.

The results obtained in cartridge assembling provide an illustration of the influence of different types of work on productive efficiency. When using trays capable of holding 750 units, the average time taken to complete the component operations of stacking, assembling, and pushing down wads was 15, 45, and 6 minutes respectively. One would accordingly expect that an increase in the duration of the first and last operations would result in a higher output per unit of time, but when pushing down wads the reverse effect was observed in trays of 1,250 and 1,500 capacity. This process, which involved much effort and accuracy of movement, appeared to be very fatiguing and was disliked by the operatives. Stacking, on the other hand, was a comparatively easy and simple operation, and in every case the rate of working continued to increase with increase in the duration of the stacking process. Assembling also, was a typically light repetitive task, and it was not until trays capable of holding 1,250 units were used that the rate of working showed signs of being impaired. The results accordingly suggest that the duration of the most productive period will depend upon the nature of the task performed, and must be curtailed when the operation is conducive to fatigue.

The foregoing considerations appear to harmonise with the hypothesis that fatigue produced by light repetitive work is more local than general. A suitable change in the form of activity seems to utilise comparatively unused parts of the body mechanism, thereby providing a situation which is favourable to productive activity. It would accordingly appear that if the most satisfactory results are to be obtained, a muscular process, for instance, should preferably be followed by one which is predominantly mental, or an operation involving standing by one involving sitting. In most industrial departments there are operations of a widely different nature which might be organised so as to provide the workers with a certain amount of variety of occupation.

Continuous unvaried activity is also conducive to boredom, which is usually most marked and causes a reduction in output about the middle of the work-spell (*cf.* Figs. 1 and 7). Changes in the form of activity tend to neutralise or retard the onset of boredom, and the steadier rate of working observed under such conditions is partly attributable to a diminution in the amount of boredom experienced.

Changes in the form of work also tend to produce an increased rate of working in the early stages of the work-spell (*cf.* Figs. 6 and 7). The anticipated change seems to create a more buoyant attitude towards the task, and diminishes the inhibitory effects produced by the prospect of an unbroken spell of uniform work.

In addition to the possibilities and advantages already discussed, the adoption of suitable changes in the form of work will be found particularly serviceable when increased output is temporarily required in any department or when the staff is depleted by absenteeism. In such cases it would be possible to draw upon experienced workers from other departments and thereby avoid loss of trade or dislocation of work Such a procedure would necessarily require the learning of two or more operations by each operative, but the disadvantages attendant upon such a policy would be more than balanced by the benefits derived.

It is frequently asserted that operatives accustomed to uniformity in the methods and conditions of work are reluctant to change to a more varied form of procedure. This attitude is merely another illustration of the inertia produced by long-established habit and the desire to live along the lines of least resistance. There is little doubt that operatives who have had experience of both uniform and varied conditions of work, generally prefer the latter and the results obtained in this enquiry support this view.

Summary of Conclusions.

The results of the investigations considered in this report indicate that, in the case of light repetitive work—

(1) Uniformity in the method of procedure is generally less productive and conducive to greater irregularities in the rate of working than are varied forms of work.

(2) The highest output is obtained when the form of activity is changed after 1½ or 2 hours of unvaried work.

(3) Many changes are detrimental to output because of their interference with the swing of work.

In addition, there is a certain amount of evidence to show that

(4) In repetitive work of a fatiguing nature, changes in the form of activity should be relatively more frequent.

(5) A high degree of resemblance between the alternating forms of activity, although subjectively satisfying, is not conducive to increased output.

APPENDIX.

SOME ADDITIONAL DATA OBTAINED.

(A) MANUFACTURE OF CIGARETTE-TINS

(a) *Conditions of work.*

The process observed in this factory was the fixing of air-tight lids to cigarette-tins In carrying out this operation, the girls stood at a bench in positions 1, 2, and 3, as shown in Fig. (8).

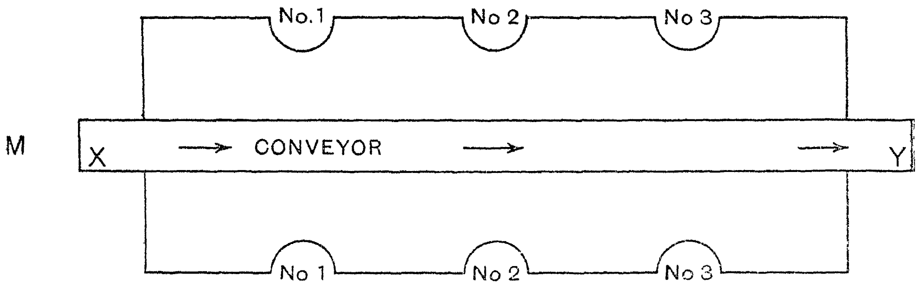

FIG. (8). Diagram illustrating conditions of work (Cigarette-tin process.)

The body was delivered from a machine at M along the conveyer XY, at an average rate of 111·7 per minute. Each girl was provided with a box containing the lids, and as the tins arrived, each was taken from the conveyer, fitted with a lid, and replaced on another conveyer on a higher level. The girls in positions 1 dealt with as many tins as possible as they were received from the machine. The surplus passed on to the girls in position 2, and occasionally these girls had to wait a few moments before a tin arrived. The lack of a continuous supply of tins was much more noticeable in position 3, and the arrival of one tin was often separated from that of the next by an interval of several seconds. Thus the girls were fully employed only when working in position 1, whereas those in position 3 were actively employed for a little more than half the time. For this reason, it was customary to change the positions of the girls each day, those working in position 1 going to position 3 and afterwards to position 2.

The hourly output of six girls was first obtained over a period of three weeks. During the two following weeks the positions of the operatives were changed at different times within the spell of work according to the following scheme :—

Worker	8.0 to 10.30	10.30 to 12.0	12.0 to 1.0	2.0 to 3.45	3.45 to 5.0	5.0 to 6.0
A ..	1	3	2	1	3	2
B ..	1	3	2	1	3	2
C ..	2	1	3	2	1	3
D ..	2	1	3	2	1	3
E ..	3	2	1	3	2	1
F ..	3	2	1	3	2	1

The figures in the table refer to the positions shown in Fig. (*a*).

On the following day each pair of operatives would start in different positions, and so on throughout the period of the investigation. Under this system, periods of strenuous activity (position 1) were followed by periods of comparative ease in each work-spell, and the longest period of work in position 1 always occurred in the early part of the spell.

(b) *Results obtained.*

The average hourly output, taken over a period of three weeks under the original system of work, is given for each worker in Table A.[1]

Table A—*Average hourly output (in gross) for each operative in positions* 1, 2, *and* 3

	Including stoppages.			Excluding stoppages		
Worker.	No 1.	No 2	No. 3.	No. 1.	No 2.	No. 3.
A	7·33	6·33	3·89	8·55	8·22	4·70
B	7·24	6·33	3·76	8·44	8·22	4·55
C	8·03	7·08	4·17	9·71	8·26	5·41
D	7·64	6·67	4·00	9·24	7·77	5·19
E	6·67	5·85	3·87	7·96	7·04	4·52
F	7·29	6·72	4·25	8·51	8·13	4·96
Avg.	7·37	6·50	3·99	8·74	7·94	4·89

The results in the first three columns make no allowance for machine stoppages and time lost in starting and stopping work, and accordingly show the actual hourly output obtained. Those in the last three columns indicate the output which would probably have been obtained if the work had been continuous They are proportional to the actual rate of working of the operatives (when free from interruptions) in the different positions. The working capacity of the operatives is given by the results in position 1 (excluding stoppages) because this is the only position in which the operatives never had to wait for a supply of tins.

The average hourly output of the six workers (including stoppages) was 5·95 gross, and the possible output (i.e. excluding stoppages) 7·19 gross. Thus the approximate loss in output due to stoppages was 17·2 per cent. The existing arrangement of work was also responsible for the decrease in output observed in positions 2 and 3. The difference in the rate of production of the operatives when in positions 1 and 2 was 9·2 per cent., and between positions 1 and 3, 44·1 per cent. Thus the usual method of work was uneconomical, since it failed to keep the operatives fully employed, and consequently reduced their productive and earning opportunities.

The preceding results suggested the advisability of modifying the conditions of work. Instead of changing the positions of the operatives each day (the usual procedure), they were moved at different times within the spell as indicated on p. 26. The results obtained under the modified conditions are given in Table B, which also includes the results obtained in position 1 under the former method

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[1] The hours of work in this factory were from 8 to 1 and from 2 to 6, and a piece-rate system of payment was in vogue.

Table B.—*Comparison of output in position* 1 *under old and new methods of work.* (*Output expressed in gross per hour*).[1]

Worker.	Old Method.	New. Method	Per cent increase.
A	8·55	9·61	12·4
B	8·44	9·61	13·9
C	9·71	10·41	7·2
D	9·24	9·73	5·3
E	7·96	8·50	6·8
F	8·51	9·33	9·6
Avg	8·74	9·53	9·2

The results show that the new arrangement of work was responsible for an average increase in output in position 1 of 9·2 per cent.[2] Work in positions 2 and 3 was undoubtedly comparatively restful after a period of activity in position 1, and the simple device of changing positions more frequently was a distinct improvement upon the original procedure. The operatives also preferred the new arrangement, and presumably found it less tiring and more varied than the continuous activity in position 1.

The nature of the variations in the rate of working throughout the day during the two comparative series is shown in Fig. (9). The curves refer to the results obtained in position 1, and indicate the average output (in gross) during each half-hour of the day.

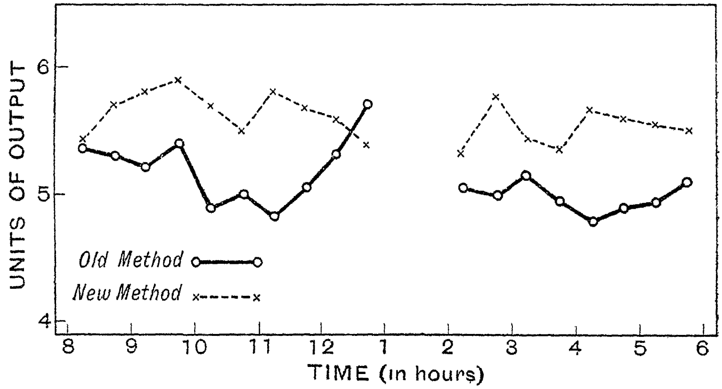

Fig. (9). Comparative rate of working under old and new conditions of work.

The curves corresponding to the more frequent changes in position are very different from those obtained under the usual conditions of work. The improvement in the rate of working is very noticeable and is maintained throughout the day. Evidently the greater variety in the conditions of work, involving shorter periods of strenuous activity in position 1, tends to retard the onset of factors detrimental to working activity.

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[1] Positions 2 and 3 are not included in the table because of the inadequate supply of tins in these positions.

[2] i.e. Although the *total* output remained unchanged because of the limited supply of tins, the workers when fully employed (position 1) were able to increase their output by 9·2 per cent. under the modified conditions of work.

The curves relating to the more uniform conditions show that, in the morning spell, there is a general tendency for the rate of working to decrease during the first 3½ hours, after which a rapid improvement is noticeable as the end of the spell is approached The curve for the afternoon spell shows similar, though less marked tendencies. This type of curve is characteristic of work where the conditions are monotonous, but not fatiguing. The improved rate of working in the early part of the spell under the new conditions suggests that the prospect of an early change in position creates a more favourable attitude towards the task, and acts as an additional incentive to activity.[1]

(B) TRAIN-ASSEMBLING.

(a) *Conditions of work.*

This process constituted one of the operations in the manufacture of recording instruments for electrical meters. It consisted essentially in fixing a small wheel between two brass plates and adjusting the arrangement so that the wheel revolved freely and truly. The cycle of movements included the boring of holes in the plates in which the axis of the wheel was afterwards inserted , adjusting the wheel to the plates , screwing the plates together, and balancing the movements of the wheel.

Four girls were observed on days when each unit of output was completed before passing on to the next, and afterwards when similar component operations, such as boring, were first performed in connection with several units before proceeding with the next operations (inserting, screwing, and balancing) In the former arrangement the changes in activity were more numerous than in the latter

(b) *Results obtained.*

The average number of units completed per day by each worker when adopting the two different methods is given in Table C.[2]

Table C.—*Average number of units completed per day under ordinary* (O) *and more varied* (V) *conditions of work*

Worker.	O	V	Per cent. difference.
A	90	77·4	−14·0
B	90	78·5	−12·8
C	90	75·6	−16·0
D	90	73·7	−18·1

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[1] It is interesting to note that prior to this investigation, each operative was supplied with five gross of lids at a time, but in order to obtain a more suitable unit for observational purposes, the lids were supplied in three gross lots during the investigation. On the completion of the enquiry, the operatives objected to a return to the original conditions of supply, and have continued to be supplied with the smaller number. It would appear that the shorter time required to complete three gross is more satisfying than the longer period required for five gross. A certain amount of pleasurable satisfaction is evoked by the successful completion of a task even though it is only part of a larger whole. Such periodic phases break up the monotonous uniformity of work and increase the pleasure in activity. The principle involved in this incidental feature of the work appears to be important, and could be applied to many industrial situations.

[2] Each girl was observed over a period of five days, and was paid on a piece-rate basis. The hours of work were from 8 to 12.30 and from 1.30 to 5.30.

The results show that under the more varied conditions of work, the output was consistently lower than on days of less varied activity. The average decrease was 15·2 per cent., and varied from 13 to 18 per cent. in the case of the different workers.

It will be noticed that the daily output of each operative under the ordinary method of procedure was 90 units This represents the effect of working to a fixed standard of output, which was accepted by the management as suitable and sufficient for the process under consideration. Since some of the operatives (e g. A and B) were clearly capable of exceeding this standard, a still greater difference in the output arising from the two methods of procedure would probably have been found if the operatives had expended the same amount of effort in both cases.

The causes of the observed differences in output can be attributed almost entirely to the greater number of movements and interruptions to activity involved in the more varied process. In the ordinary method of procedure, the worker, using the same tool throughout, could partially complete several units without interruption, but under the more varied method, she was constantly changing tools and in many cases had to wait before she could borrow the necessary implement from a neighbour In the more varied process each minor operation occupied only a few seconds, and was followed by an entirely different activity of approximately the same duration. Thus the numerous changes in the form of activity, the absence of rhythm in the method of work, together with the time lost in waiting for tools and in changing from one activity to another are quite sufficient to account for the lower output observed in the more varied form of procedure.

The results obtained in this particular process accordingly illustrate the undesirable effects of too many changes in the form of activity. Such conditions not only have an unfavourable effect on output, but are also disliked by the workers.

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INDUSTRIAL
FATIGUE RESEARCH BOARD.

REPORT No. 53.

The Use of Performance Tests of Intelligence in Vocational Guidance.

An Investigation conducted for The National Institute of Industrial Psychology

By F. M. Earle, M.Ed., B.Sc., M. Milner, B.Sc. and other Members of its Staff.

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PREFACE.

The Industrial Fatigue Research Board in 1927 published a report embodying the results of an experiment on Vocational Guidance conducted jointly with the National Institute of Industrial Psychology. This experiment, in view of its preliminary character, was planned so as to demonstrate the possibilities of vocational guidance rather than to obtain results of definitely practical value, and was accordingly limited to a small scale involving only one hundred children. The Board were subsequently advised that the continuance of research on a more extensive scale had been made possible through the generosity of the Carnegie United Kingdom Trust, who had approved a grant to the National Institute of Industrial Psychology for this purpose.

The practical conclusions to be drawn from this second experiment, which has been conducted under the supervision of Mr. F. M. Earle, are not yet available, but it has already produced certain results of scientific interest thanks to a grant received by the National Institute of Industrial Psychology from the Laura Spelman Rockefeller Memorial. These have been offered by the Institute for publication in the Board's series of reports.*

The first contribution of these results appears in the present report. The tests used in the main experiment have included a number of performance tests of intelligence, that is to say, tests in which intelligence is measured by the performance of some specific act and without recourse to language either oral or written. The results of these tests have been analysed with two objects, first to determine whether the tests used are satisfactory instruments of measurement, and secondly to discover the nature of the abilities measured by the separate tests. The analyses (which are given in detail) have reference, *inter alia,* to the standardisation of the tests at school leaving age, to the influence of general intelligence upon success in these performance tests, to the possible presence of a group factor connecting tests in which spatial elements enter, and to the relation between success in some of these tests and success in certain manual trades. The results of these analyses lead to certain conclusions of special interest to vocational psychologists.

January, 1929.

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* An earlier report, entitled Occupation Analysis, and based on the same experiment on vocational guidance, has been published by the National Institute of Industrial Psychology.

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THE USE OF PERFORMANCE TESTS OF INTELLIGENCE IN VOCATIONAL GUIDANCE.

BY

F. M. EARLE, M.Ed., B.Sc., M. MILNER, B.Sc., and others.*

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* The following members of the staff of the National Institute of Industrial Psychology also took part in the experiment: A. Macrae, M.A., M.B., Ch.B., M. B. Stott, M.A., F. Gaw, B A., and A M. Hudson Davies, B A.

I.—Introduction.

1.—GENERAL PLAN OF THE REPORT.

The scheme of the Experiment in Vocational Guidance carried out by the National Institute of Industrial Psychology has been already outlined in two progress reports issued by the Institute. A more detailed account of the procedures and methods therein employed will be published later ; but in view of the space required for an adequate study of each type of test used, it seems desirable to consider selected aspects of the Experiment in a series of special reports. This report is one of them. It deals with Performance Tests of Intelligence used for purposes of vocational guidance at school-leaving age. The fact that the purpose was a special one explains both the selection of tests and their limited application to one age group. The object of this report is to give not only an account of the tests used and the scores obtained by the children examined but also a study of the basic abilities required for success in the tests. It is only as we gain fuller information concerning the latter that we can employ tests in vocational guidance to the best advantage.

2.—MEANING OF THE TERM " PERFORMANCE TEST."

A " test " is usually understood to mean a trial of strength, knowledge, skill or ability, and a person's capacity is very frequently judged by the amount of knowledge he possesses or by the degree of skill he displays in some activity or process in which such skill is conveniently expressed. A blacksmith shaping a horse-shoe and a cricketer defending his wicket are both being put to a test of their skill.

Tests may be of various kinds according to the material they employ or according to their purpose ; thus, for example, scholastic tests aim at measuring attainment in school subjects, intelligence tests seek to gauge general educable capacity, while trade tests are usually designed to show the extent of a person's mastery of some particular trade or occupation. But within recent years attempts have been made to distinguish between—

(i) tests which give evidence of inborn or innate ability, and
(ii) tests which measure the extent to which some particular knowledge or skill has been acquired, without endeavouring to disentangle the diverse influences of innate ability, instruction, practice and the like.

Of course, since native ability affects all our learning, this distinction is a difficult matter and a special technique of examination is necessary in order to secure it. Tests devised for this purpose have been called " psychological tests " because they are based upon a careful analysis of the psychological processes which underlie the activities in question. The so-called " Performance Tests of Intelligence " which form the object of this report are of this kind and are primarily intended to give evidence of inborn abilities.

Performance tests in general are practical problems which require for their solution the manipulation of some concrete material or the performance of some specific act. No response in language, whether oral or written, is usually required. Sometimes the problem is presented in pantomime without the use of words; but for most purposes it is found convenient to give the instructions in simple language, and in using such tests for purposes of vocational guidance this is always done. In the early stages of the development of psychological tests, practically all the performance tests which were sufficiently standardised for general use were designed to measure the mental function (or functions) known as "general intelligence."[1] There is no reason, however, why the term "performance tests" should not be applied more widely to include tests which do not primarily aim at the measurement of general intelligence. Thus, for example, practical problems may be devised in which some acquired skill or some special technical knowledge contributes largely to their solution; such problems belong to the second class mentioned above, they test the amount of skill or knowledge that has been acquired. The chief feature of performance tests regarded from this wider standpoint is that they call for the performance of some specific act, and consequently may demand certain degrees of bodily control and manual dexterity. If, in such tests, the control of movement is itself one of the principal features of the response, as for example, in tests of manual dexterity, the evidence provided by such tests must differ greatly from that given by tests in which mental processes are relatively the most important factors in success. In many performance tests, however, movement is only a means to a desired end—the solution of the problem—and in this solution the processes of analysis and synthesis in thought may be far more important than the movements and manipulations which express them. This is the case in those performance tests which we are about to consider. They have all been designed as tests of intelligence, and although in all of them some manipulative processes enter, the influence of the latter upon success appears to be slight.

An account of the early development of the best known performance tests of intelligence, together with the instructions and norms proposed for English children and a discussion of the value of the tests, will be found in Miss F. Gaw's report to the Industrial Fatigue Research Board.[2] In a report on a joint investigation conducted by the Industrial Fatigue Research Board and the National Institute of Industrial Psychology[3], the use of these tests for purposes of vocational guidance received fuller discussion.

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[1] Or, alternately, on Spearman's theory, the general factor "g."

[2] Gaw, F. (1925): Performance Tests of Intelligence. *I F.R.B. Report No.* 31. *London, H.M.S.O.*

[3] Burt, C. & Others (1926): A Study in Vocational Guidance. *I.F.R.B. Report No.* 33. *London, H.M.S.O.*

3.—THE NEED FOR PERFORMANCE TESTS IN VOCATIONAL GUIDANCE.

As is generally known, the first systematic scale of tests of intelligence was that devised by Binet.[1] Many of these tests require considerable skill in the use of language and in the interpretation of abstract ideas, but there are also included a number of practical problems (such as the "three commissions," "discrimination of weights," and "memory for designs") which are performance tests in the sense described above. As, however, they are relatively few in number, it has been customary to regard the Binet scale (and its variants) as predominantly verbal, and its results as dependent on the ability to understand and to use language.

For this reason performance tests of intelligence have been described as "non-verbal," even though the instructions be given through the medium of language. This is legitimate, since the grading of the tests and the language of the instructions is such that failure through inability to comprehend the instructions very rarely occurs. Moreover, the problems can readily be solved by mental processes in which language does not appear to play any important part.

The use of performance tests of intelligence has been advocated for several reasons. Their use with children at low mental levels or with children who may be unacquainted with the particular language which it is desired to employ requires no justification in this report. In the case of other children, however, it is necessary to consider why a verbal type of test (group or individual) may not be sufficient.

It has often been stated that tests in which the response is to be expressed in language, either by word of mouth or in writing, unduly favour those who are described as "talkers" rather than "doers." Burt,[2] for instance, found that certain children obtained a higher score in the Binet tests than could be justified by their achievement in other directions. Such individuals generally exhibit considerable fluency in verbal expression, but the superficiality of their success is disclosed when reasoning, judgment and foresight are demanded. Burt also found that a child's success in the Binet tests is, in a considerable degree, a measure of his "schooling."[3] Such tests, therefore, may not give an entirely satisfactory estimate of a child's native ability. The remedy would seem to lie in the introduction of a greater proportion of practical problems.

---

[1] Binet, A. & Simon Th.: "Le dévelopment de l'intelligence chez les enfants." *Année psychologique*, 1908.

[2] Burt, C. *Mental and Scholastic Tests* (Reports to the London County Council). London, P. S. King & Co., 1921.

[3] Burt, op. cit. The Binet tests are, of course, measures of something besides schooling.

But although the Binet type of test may allow some children to gain greater credit than they deserve, it may serve its purpose reasonably well for the majority. Much depends upon the purpose for which the tests are given. If our object is to forecast a child's future progress in school, an examination of limited range may be entirely satisfactory, and the Binet type of test does in fact serve this purpose well. On the other hand, if the child's fitness for a particular occupation be under consideration, a wider range of examination may well be needed.

This raises the important point of the connection between success in school pursuits and vocational success. For the majority of children who leave school at 14 years of age the occupations to be considered are essentially practical ; and it has often been remarked that there appears to be little relation between success in school and success in after life. The lack of scholastic attainment in many who are successful in business and in industry is constantly observable. It follows, therefore, that tests which bear a close relation to the abilities needed for success in school may not give much indication of the prospect of success in occupational life.

Another reason for using practical tests originates in the view that some children exhibit greater interest in these situations than they do in the more abstract problems of the verbal tests, and therefore, by putting forth greater effort, do themselves fuller justice. The same view, in another aspect, is responsible for the belief that there is an " academic " type of mind which is favoured by the verbal tests and which is not nearly so competent in situations of a more practical nature.

It is as yet by no means certain that such distinctive types exist, at least in the extreme forms of " abstract " and " concrete." But if their existence could be established by experimental investigation, it would be of great significance both from an educational and from a vocational point of view Apart from this, however, it is clear that a wider range of tests, including some which bear upon the abilities needed in industrial and allied occupations, must be devised and standardised for the purposes of vocational guidance. For these reasons the assistance to be gained from the use of Performance Tests of Intelligence was very carefully considered and it was eventually decided to employ several of those tests which had been found useful in an earlier experiment in 1923.[1]

4.—THE SELECTION OF CHILDREN FOR EXAMINATION.

Six hundred children, selected at random from among those who were due to leave school in any one term, were advised concerning their choice of an occupation. On the whole they constituted a fairly representative sample of children attending elementary schools in a London district where the general prosperity was perhaps slightly below the average for a working class population. They were attending, in all, sixteen schools; but the differences between the populations served by these schools were small.[1]

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[1] *See* p. 5 reference to Report No. 33 of I.F.R.B.

Of the six hundred children who were advised, five hundred and seventy were given the performance tests of intelligence and the results reported here refer, for the most part, to these.

5.—Age of Children Tested.

The general rule in an elementary school is that pupils must remain until the end of the term in which their fourteenth birthday falls. Since the Institute's enquiry was carried out during the last school term of each group of children, their ages varied from 13 years 9 months to 14 years 1 month. The great majority, however, were under 14 years (median age 13 years 10 months ; quartiles 13 years 9 months and 13 years 11 months).

6.—Nature of the Examination

All the children were examined for general intelligence by means of a group test of the verbal type, and 170 of them received an individual examination by means of a revised form of the Stanford version of the Binet Scale,[2] In addition the following performance tests of intelligence were given :—

1. Mazes (Porteus).
2. Cube Imitation (or Knox Cube Test).
3. Substitution (Woodworth and Wells)
4. Picture Completion, II (Healy).
5. Formboard (Dearborn).
6. Cube Construction.
7. Picture Completion, I (Healy).
8. Formboard (Goddard).
9. Profile Test.

These tests were taken from the series described by Gaw[3] and standardised by her for English children. It was found necessary to make some changes in the instructions and in the details of scoring, and the revised versions of the tests are given below. It is necessary to emphasise the fact that the revised norms and remarks here made are intended to apply only to the age groups specified.

Since it is necessary to examine the results in some detail, it seems advisable to discuss each test separately. Before doing so, however, some general points require attention.

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[1] For further details of the experiment see the main report (to be published later).

[2] This is the unpublished London version revised by Burt, Spielman and others in co-operation with London school teachers.

[3] Gaw, op. cit.

7.—AIMS OF ANALYSIS OF RESULTS.

The scores obtained from the application of tests to any large group of persons may be analysed with two different objects—first, to determine whether the tests used are satisfactory instruments of measurement, and, secondly, to discover the abilities of the persons measured.

(i) Examination of the distribution and range of scores will provide information as regards the first of these objects. If the group to be examined is sufficiently large and has been randomly selected, and if the test is of suitable difficulty (neither too easy nor too hard for the average person), the scores obtained will generally be distributed according to the "normal" frequency curve. If they are not, an explanation may be found in the difficulty of the test, in the conditions under which it is given, or in the composition of the group of persons examined.

(ii) The discovery of the abilities of the persons tested depends on the standardisation of the test. In the present state of psychological knowledge, scores can only be interpreted comparatively. Such comparisons can be made in several different ways. The relative merits of such methods as mental age and percentile ratings must be carefully considered before a choice is made.

In addition to giving a quantitative meaning to the scores, it is also necessary to determine the nature of the abilities tested. This task may be approached in two ways—(i) by comparing an individual's score in a given test with his efficiency and achievement in different kinds of work; (ii) by comparing his scores in as many different kinds of tests as possible. Both methods have been employed in this enquiry.

8.—GENERAL INTERPRETATION OF TEST SCORES.

It has been usual to express the results of a test of intelligence as a "mental age." To obtain mental age norms, groups of children must be examined at each age for which norms are required. Such groups should be adequately representative of that section of the population from which they are drawn. The median score[1] for each group is then taken to be the mental age norm, this being, by hypothesis, the same as the median chronological age. Mental age norms obtained in this manner are given by Pintner[2] for some, and by Gaw[3] for all of the tests here described.

The conception and use of a "mental age" has developed in connection with intelligence tests of the Binet type. It has been shown that ability in such tests increases progressively with age, although the increment per year gradually decreases.[1] In the case of performance tests, however, the mental age norms established do not show a progressive increase from age to age. For instance, in the Cube Imitation test, as will be seen (page 15), the same median score of 7 is gained by age groups 10, 11, 12 and 13. There are clearly two possible reasons for this.

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[1] The median score is the middle score when all are arranged in order from high to low.

[2] Pintner and Paterson. *A Scale of Performance Tests.* New York, Appleton & Co., 1923.

[3] Gaw, F., op. cit.

First, each of these tests may measure some ability which has only a slight connection with that measured by intelligence tests and which develops much more unevenly than does intelligence itself. Against this must be set the fact that each of the performance tests is significantly correlated with two different intelligence tests (*see* below p. 40). Nevertheless, this correlation is not high; hence the special abilities required in each test may exert greater influence. Secondly, it is possible that while the special abilities tested do increase from age to age, the limitations of the test and the nature of the scoring prevent such increase from being disclosed. For instance, in the Cube Imitation test it may well be that this particular ability does develop between the ages 11 to 13, but that the increase cannot be measured by the test in its present form. It is a difficult matter to grade the various parts of any test problem so that it will measure small differences in an ability at all stages of growth; and this difficulty is increased in the case of performance tests by the fact that each consists of comparatively few items. This being so no finer discrimination by mental age norms is to be expected.

For these reasons, in using these tests for the purpose for comparing children of 13–14 years of age, we have preferred to use the method of percentile ranks. Each child's score is expressed as a rank relative to the remainder of the children in the group, this rank being reduced to a percentage. Thus, supposing the scores obtained for any group of 100 children are arranged in order of merit for the test concerned, the worst child will occupy the percentile rank approximating to zero, the best child the percentile rank approximating to 100, the middle child the 50th percentile rank and so on. A child whose percentile rank is 55 has gained a higher mark than 55 per cent. of his competitors. It is comparatively simple to find the percentile rank corresponding to any given score for any given group,[2] and therefrom to determine the relative standing of any member of another group similarly selected. Percentile ranks in Performance Tests of Intelligence for elementary school children of 13 years 10 months are shown in Table XVII. The quartiles shown in the other tables are the 75th and 25th percentiles respectively.

On the other hand if we follow the usual method of interpreting the results of a comprehensive series of performance tests, we should regard the median of all the separate mental ages determined for each test as a measure of the child's general level of ability. This median would then be taken as comparable with the mental age obtained from the Stanford-Binet scale, and accordingly it should be divided by the child's chronological age to give a corresponding "Intelligence Quotient" for the series.

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[1] Cf. work of Burt, Terman, Thorndike and others.

[2] Cf. any textbook dealing with education measurements, e.g., Otis "*Statistical Method in Educational Measurement.*"

This method of combining scores is based on two questionable assumptions. First, that the separate scores in terms of mental ages are reliable and evenly distributed about the median. This, it seems to us, on the results of our experiment, is not the case at the age of thirteen. Secondly, that the combined score truly represents an ability which is common to all tests ; if it does not, then a combined score is obviously misleading. To gain information on this point it is necessary to inquire into what is actually measured by the tests, individually and collectively. The comparative studies referred to on p. 6 in which the relation between the abilities required in different tests is examined will, of course, be helpful in this connection. They are given in Section III of the report.

9.—The Estimation of Temperamental Factors.

In addition to merely recording test scores, careful observations were made as to the subject's behaviour during testing. Signs of such reactions as interest in the material, undue anxiety as regards mistakes, confidence, persistence in spite of difficulty and the like were particularly noted; for peculiarities of behaviour during testing are of great importance both in the interpretation of test scores and in formulating judgments as to the individual's temperamental qualities. It must be borne in mind, however, that any emotional reactions or attitudes manifested during the test situations may be specific to the circumstances. It would be rash, for example, to say that a child who refused to abandon the cube construction problem until he had reached a successful solution must therefore be persistent in general. Observations from tests afford merely indications ; they need confirmation by further evidence.

II.—Description and Results of the Tests[1].

1.—Maze Test. (Porteus.)

Material.—This test consists of a series of nine straight-line mazes, printed on separate sheets and graded progressively in difficulty for children between the ages of five and fourteen.

---

[1] The procedure and instructions as given by Gaw (op. cit.) are here reproduced in full, with certain amendments. Such amendments are in no case extensive ; in most cases they are merely attempts to avoid ambiguities that became apparent during our experience in giving the tests.

Procedure[1].—The child is given a pencil and the maze for year V is put in front of him. The examiner says:

> " Suppose this is the plan of the paths in a garden. These lines are walls which you cannot get over. Start with the pencil from the mark at the top and draw a line to show how you would find your way out of the garden by the quickest path. Show me first of all, any openings that you can see." (*The two openings are indicated.*) " All the other paths are blocked. Don't go up any of the blocked turnings. Go down this path from the top and then out by the first opening you can find. You must not trace the path in the air first of all."

With the succeeding mazes the openings are not pointed out first of all. Emphasise that the child must find his way out without turning up any of the blocked paths; as soon as he enters a blind alley and has discovered that he is blocked, do not allow him to correct his mistake by retracing his path, but give him a fresh sheet of the same maze, for a second trial. If for some reason . . . . . a third attempt seems needed, invert the diagram and treat it as a new test.

Porteus states that the tests need be continued only until the child entirely fails with two successive mazes. Burt suggests that, unless it is plainly evident that the remainder are too hard, each child should be allowed to attempt every test.

Scoring.—One mark is awarded for each test correctly performed on the first trial. Half a mark only is allowed if a second trial is necessary for success, or if in the test for year V the child passes out of the second or lower opening. To the total number of marks thus gained, add four marks for presumable success in imaginary tests for ages I to IV; the result will give the child's score roughly in terms of a mental age. There is no test for age XIII. But four trials are allowed with the mazes for ages XII and XIV. With that for age XII a full mark is allowed for success in any of the first three trials; and half a mark for success in the fourth. But with the maze for age XIV two marks are allowed for success in the first trial; and for every further trial needed half a mark is deducted. Thus a child who does not succeed until the second trial scores only one and a half and so on.

Results.

(a) *Sex differences.*—The median scores for boys and girls are almost identical and the differences between the mean scores and interquartile ranges are very small. This is in agreement with Porteus's own statement that in this test boys and girls at the age of thirteen are practically equal. (Figures 1 and 2, Tables I and XVII).

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[1] The procedure and scoring for this test are those used with English children by Burt, and described in "*Mental and Scholastic Tests*" (cf. footnote p. 6) from which this section has been taken.

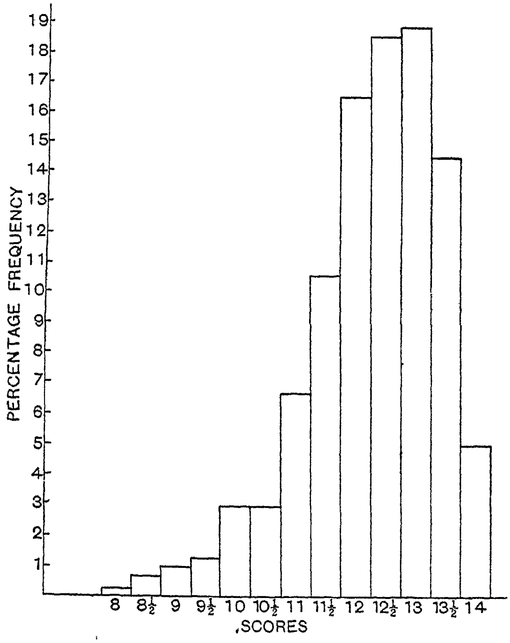

Fig. 1.—Porteus maze tests. Distribution of Scores: boys

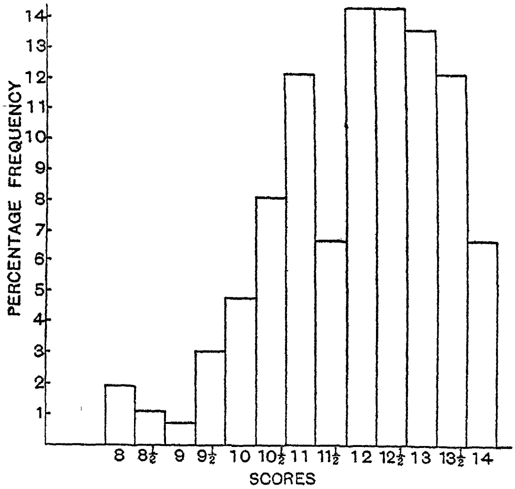

Fig. 2.—Porteus maze tests. Distribution of Scores: girls.

(b) *The range of scores.*—This is shown in Table I.

TABLE I.—*Range of Scores for Maze Test.*

—	—	No. of cases	Median.	Quartiles.	Standard Deviation.
This group ..	Boys	300	12·4	11·7 —13·1	1·12
	Girls	270	12·1	11·10—13·05	1·38
Gaw[1] ..	Boys	52	12·5		1·30
	Girls	48	12·5		1·50

(c) *Remarks.*—The median score for the Maze test given by Burt[2] for 13-year-old children is 13·2 (for 12-year children 12·3), while the median mental age by Binet tests for the same group is given as 13·5. This suggests that the group of children under review were below the average—a conclusion confirmed by the percentile scores for Binet tests and Porteus Mazes respectively (Table II).

TABLE II —*Comparison of results of Binet and Mazes Tests expressed in mental ages for each percentile.*

	Percentiles										
	0	10	20	30	40	50	60	70	80	90	100
Burt * (13 years)	9 0	11 3	12 0	12 5	13 0	13 5	14 0	14 3	14·7	15·0	15 5
(12 years)	8 7	10 8	11 5	11·7	12 0	12 5	13 0	13·0	13 5	14 3	15·5
This group—Stanford-Binet .	8 3	9 8	10 6	11 2	11 8	12 2	12 8	13 4	14 0	11·6	16 0
This group—Porteus Mazes ..	8 0	10 4	11·1	11 6	12 0	12 3	12 7	13 0	13 3	13·6	14·0

* Mental ages. (*Mental and Scholastic Tests* Table XII, p 151)

It was also found by the independent use of the Stanford Revision of the Binet Intelligence Scale (adapted by Burt for English children) that the median mental age of this group of elementary school children was 12·3 years (mean mental age 12·0 years; standard deviation 1 year 8 months). Moreover the score distributions both for the Binet tests (170 children) and for the group tests (570 children) were approximately normal. These facts are of importance in the present instance.

Since the Porteus test stops short at year XIV, it is not to be expected that a 13-year group of children would give a normal distribution of scores, nor, in the present case, does this occur. As we should expect, a skewing occurs towards the upper end of the scale. But considering that the median score is 12·3 this is more marked than it ought to be. On examining the method of scoring it is clear that the present system of giving credits for incomplete successes is to some extent responsible for the results.

---

[1] For children of 13 years attending a school from which some of the subjects of this experiment were drawn.

[2] Burt, *Mental and Scholastic Tests.* Table XXXIV. p 222

(d) *The effect of an alteration in scoring.*—If two trials only are allowed for year XIV, two marks being given for success in the first trial, and one mark for success in the second trial, the change in the distribution of scores is as shown in Fig 3.

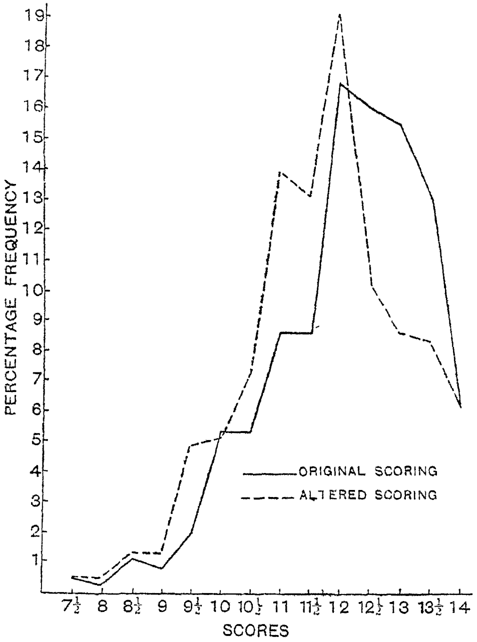

Fig. 3—Porteus maze tests. Distribution of Scores.

The median score for the group is now reduced to 11½ (the mode being 12). If the scores are to be interpreted as equivalent to mental ages, this makes the average mental level of the group appear lower than is indicated by other tests (the Stanford-Binet for example). At the same time there can be no doubt that the changed scoring gives a distribution of scores more in accord with what might be expected if the basic abilities leading to success are the same as in other tests. This is perhaps doubtful; but since the test is supposed to give a good measure of general intelligence, the point may, for the present be conceded.

Another cause of skewness, however, is the absence of such harder mazes as would give finer discrimination at the upper end of the scale. Two alterations are possible. Either—

1. The XIV-year maze is so hard in itself that other problems of intermediate difficulty between the ages of 12 and 13 are needed, or
2. The XIV-year maze is sufficiently easy but supplementary problems of greater difficulty are needed.

In this enquiry we found that only 5½ per cent. of the children examined succeeded in the first trial in the XIV-year maze. A further 14 per cent. succeeded in the second trial. As it stands, therefore, *for this group of children*, the maze is difficult enough, and finer discrimination could perhaps better be secured by additional problems of intermediate difficulty than by the present method of allowing four trials. But for a group of children of higher ability the XIV-year maze would be correspondingly easier, and consequently additional mazes of a harder kind would be a greater improvement for purposes such as we are considering.

(e) *The abilities required for success in this test.*—Our observation of individual performances confirms the causes for failure enumerated by Burt.[1]

> " The cause may be an intellectual one. The child may become confused, his power of systematic attention may be unable to cope with a task so complex ; he may be unable to follow with his unaided eye the longer paths and more devious routes, or he may fail to retain the results of his observation so as to guide the movements of his hand ; he may be unable to plan or to profit by his past mistakes. Quite as commonly the cause is partly emotional. The child may be over-confident or careless ; he seems unable to take thought beforehand, or too dashing and impulsive to carry out his thoughts."

According to Porteus himself, failure in the mazes is more significant than success. " Lack of planning capacity " is the personality trait, as measured by estimates, that correlates most highly with failure in the tests. Porteus claims that the test provides an indication of industrial and social capacity.

The test is intended to be primarily a test of general intelligence. Discussion of its value for this purpose will be found on p. 57. Some form of spatial memory is required in order to avoid mistakes after the correct route has been noted.

2.—CUBE IMITATION. (KNOX CUBE TEST.)

Material.—The material consists of five black one-inch wooden cubes

Procedure.—The examiner places four cubes in front of the subject, about 2 inches apart in a straight line. With the fifth cube he then taps the blocks according to the first line-pattern given below, about one tap per second. The cube at the subject's left (which is numbered 1) is always tapped first After each line-pattern the examiner places the fifth cube in front of the subject, about on a line midway between the third and fourth cubes, saying " Do that." The next line-pattern is then tapped, and so on till the subject fails in at least three successive patterns. The successive line-patterns are as follows :—

---

[1] Burt, C., op. cit.

a. 1–2–3–4
b. 1–2–3–4–3
c. 1–2–3–4–2
d. 1–3–2–4
e. 1–4–3–2
f. 1–4–2–3
g. 1–3–2–4–3
h. 1–4–3–2–4
k. 1–3–1–2–4
l. 1–4–3–1–2–4
m. 1–3–2–4–1–3
n. 1–4–2–3–4–1

Scoring.—The score is the number of lines correctly reproduced.

Results.

(a) *Sex Differences.*—The means and medians together with the range of scores are practically identical for boys and girls. (Figures 4 and 5 ; Tables III and XVII).

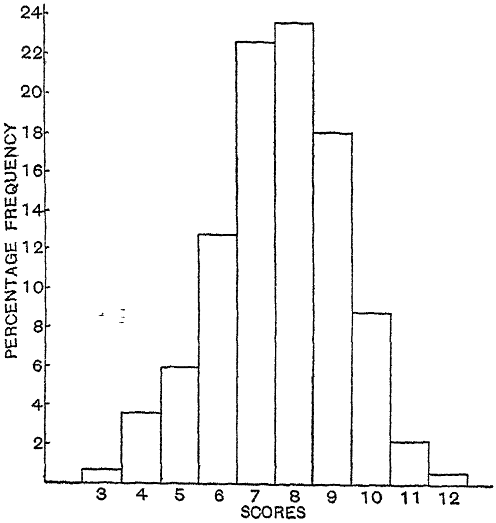

Fig. 4.—Cube imitation test. Distribution of Scores: boys.

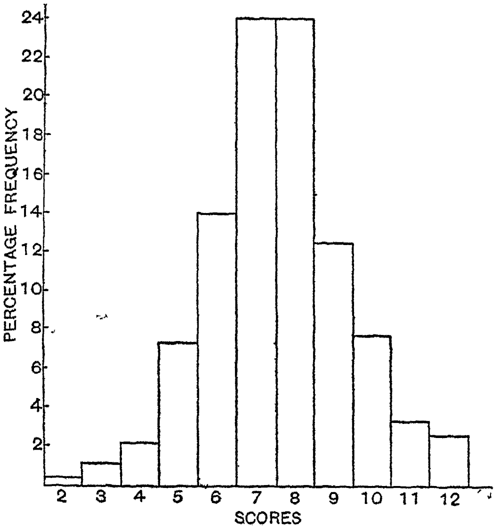

Fig. 5.—Cube imitation test. Distribution of Scores: girls

The distribution approaches the normal, although the middle peak of the curve is high and the extremes terminate abruptly. This seems due to the fact that the discriminative capacity of the test is somewhat coarse. For example the distribution according to percentile ranks (Table XVII) for boys shows the difference of score between the 40th and 50th percentile to be only ·5 and between the 50th and 60th only ·4. That is to say the present system of scoring does not admit of finer grades than whole numbers, and it is therefore difficult to see how the discrimination could be improved without radical alteration of the test.

(b) *The range of scores.*

TABLE III.—*Range of Scores for the Cube Imitation Test.*

	No of cases.	Median.	Quartiles.	Standard Deviation.
This group—				
Boys . .	300	7·7	6·6—8·7	1·7
Girls . .	270	7·5	6·5—8·6	1·82
Pintner's[1] group . .	77	7·0	6·0—8·0	—
Gaw's group—				
Boys	52	7·5	not given	1·6
Girls	48	8·0	not given	1·4

(c) *Remarks.*—According to the Mental age norms given by Gaw, there is no difference between the median scores for years 10, 11, 12, 13. Pintner also gives the same result, with the exception of year 10. Either the scoring is not fine enough to discriminate between the medians for these ages, or else children do not develop markedly in this ability between the ages of 10 and 13.

There is an obvious parallel between this test and the Stanford-Binet tests of repeating syllables and digits. It is, therefore, reasonable to suppose that if the ability to repeat a long sentence or a number of digits can only be measured at levels differing by several years of growth a similar result will be found for this test. If such be the case, all we can say of a child who obtains any given score in the test is that he has reached the particular level corresponding to that score, although in actual development he may have approached very close to the next level.

Looked at from this point of view, the test (according to Gaw's norms) is not very helpful at school-leaving age, for we found that 27½ per cent. of the children whom we examined gained a score of 9 and over, whereas a score of 8 represents a mental age of 14 years. On this basis 53 per cent. of our cases had a mental age of 14 years or over—a result which is not consistent with the findings of other tests.

---

[1] Pintner and Paterson, op. cit. p. 75. The children tested were from selected schools in Columbia that "would be very representative of the middle class in the population at large."

(d) *The ability required for success in this test.*—The behaviour of different subjects suggests that those who are liable to emotional disturbances while being tested are particularly handicapped, since control of attention is an essential factor in success. Introspective reports from the subjects indicate more than one method of memorising the sequence. A few seem to hit on the plan of mentally numbering the cubes, so that the problem becomes partly one of immediate number memory. Usually, however, the test seems to involve only immediate memory for visually presented spatial sequence The cubes are distinguished according to their arrangement in space. Hence there is a difference between this test and tests of immediate memory for numbers in which recall is greatly facilitated by verbal associations.[1] Differences in emotional reaction are also apparent. Some children express doubt and hesitancy even though they succeed in repeating a series correctly, while others show confidence when their efforts are entirely incorrect. This latter attitude seems sometimes to be an attempt to carry off the situation by " bluff."

3.—SUBSTITUTION. (WOODWORTH AND WELLS.)

Material.—The material required is a pencil, a stop-watch and a printed sheet showing at the top of a row five different geometrical shapes—a circle, a square, a triangle, etc. This constitutes the key, the five shapes being numbered from one to five. Below the key the same shapes are reprinted, in haphazard order, in five lines or rows with ten shapes in each. These shapes are not numbered.

Procedure.—The test sheet is placed before the subject and his attention is called to the key at the top. The examiner says: " There are numbers in these figures at the top (*pointing to the key*) but there are no numbers in any of these (*pointing to the five rows*). You are to fill in these (*pointing again to the five rows*) with the right numbers. Look at the key and say which number goes here, for example (*pointing to first figure*)." If the subject does not understand at once the explanation is repeated until it is reasonably certain that he does. The examiner then says: " Fill in these figures with the right numbers beginning here (*pointing to first figure*) and work along each line across the page from left to right."

The subject is not allowed to fill in first all the figures of one sort, as for example, the star, then all of another sort and so on. He must *number* them one after another as they come.

Scoring.—The total time in seconds is recorded and also the numbers of errors. For the score there is added to the total time $^1/_{50}$ of itself for each error.

---

[1] One interesting exception, however, occurred One boy was discovered who detected differences in the sounds produced by tapping the cubes, and identified the cubes accordingly. He obtained a high score

Results.

(a) *Sex differences.*—The differences between the means, medians and quartiles for boys and girls are not significant (Figures 6 and 7; Tables IV and XVII)

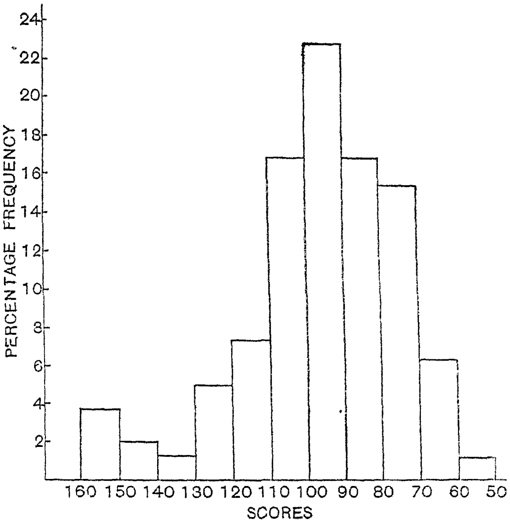

FIG 6.—Substitution test. Distribution of Scores: boys.

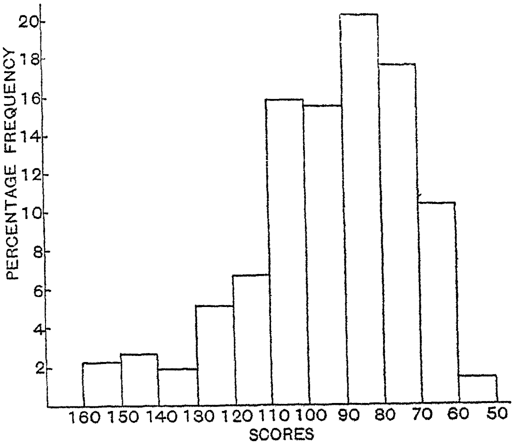

FIG. 7.—Substitution test. Distribution of Scores: girls.

(b) *Range of scores.*

TABLE IV.—*Range of Scores for Substitution Test.*

	No. of cases	Median	Quartiles.	Standard Deviation.
This group—				
Boys	300	93·5	106·5–80·5	22·2
Girls	270	90·5	105·5–76·5	21·7
Pintner's group	42	96·0	110 –85 0	—
Gaw's group—				
Boys	52	99·0	not given	—
Girls	48	97·0	not given	—

The scoring, being based on time, admits of fine grades of discrimination, but the percentile distribution (Table XVII) shows a difference of only 4 seconds between the 40th and 50th percentile ranks. Hence very accurate timing is required on the part of the examiner.

(c) *Remarks.*—The difference of 5 seconds between the 40th and 50th percentiles represents (according to Gaw) the difference in mental age from 13 to 16 plus. This we may compare with the difference (half a year) found between the 40th and 50th percentiles for Stanford-Binet tests at this age. The discrepancy is too great to be due to sampling errors. According to Gaw's age-norms, the median score for our group is better even than a sixteen-year old performance. Further proof that the task is easier for our group than might be expected from the published norms is given by the detailed comparison of the scores in the above table.

(d) *The ability required for success in the test.* Analysis suggests that success in this test depends on speed of association between the given forms and numbers. Differences of method can occur between those who learn the key quickly and then trust their memory, and those who being more cautious refer each time to the key. The test situation does not seem to arouse any specific emotional reaction other than that common to all tests scored by time—that is, the inhibitory effect of excessive effort after speed.

4.—PICTURE COMPLETION, II. (HEALY.)

Material.—For this test the materials consist of a set of eleven pictures, mounted on two pieces of wood measuring 11 in. × **11·5 in.** and a set of sixty small pictures, also mounted on wood. The pictures which make up the set of eleven, represent as many different scenes in a school-boy's day.[1] In each scene a square hole has been cut (removing some essential object) which has to be filled with a suitable piece selected from the set of sixty small pictures.

Procedure.—The examiner places the set of pictures in front of the subject and the box of small pieces at the side where they can be seen and reached easily. Before the subject begins the test, the examiner must make sure that the small pieces are in their proper order in the box., i e. in the order determined by the numbers printed on the back of the pieces. He must also be sure that the eleven scenes are set out in proper order and that the demonstration scene comes at the subject's left. The examiner then says :—

> " Here is a story told in pictures. The story begins here (*pointing to demonstration scene*) where the boy is getting dressed. It shows the same boy, remember—the same boy, doing one thing after another during the same day (*examiner points along the first row, then along the second, to indicate sequence clearly*). You see in each picture a piece is missing. Here (*pointing*) are a lot of small pieces. They fit in any of the spaces, but there are more pieces than you can use. You are to pick out the piece that you think is needed, that is best to complete the sense of the picture. For instance, what is missing here ? (*point to demonstration scene*). Yes, a boot (*if incorrect answer is given examiner says*: No, he is dressing, and he is stooping for his other boot)."
>
> " Now which is the boot that he must have ? Yes. This (*pointing to shoe*) wouldn't be right, because he must have a boot to match the other one. That is the way each picture is to be done. There is always some piece that is the best one. You can tell which it is by studying the picture. Now go ahead."

The examiner gives no more help, and says nothing further, except, if the subject asks, to tell him he may change his moves. When all the spaces are filled, the subject is asked if he is quite satisfied. If not, he is told he may make changes.

The time limit is twenty minutes

Scoring.—The accompanying table (Table V) is used in scoring. The final placings only are considered and the points of credit for each of these placings are read from the table. All placings which are not scored in the table (i.e. those which represent marked absurdities) are counted as minus 5 (—5). For example, piece 19 in Picture I would be absurd Hence we find that in the column headed I the space opposite 19 is empty, so that if this piece is put into this picture it is to be scored minus 5. For the total score the minus values are subtracted from the plus. The value representing the best piece for each picture is italicised in the table. The demonstration scene is not counted since the correct piece (boot) is left in position after the demonstration. Ten pictures remain to be dealt with

---

[1] In order to make the test more suitable for use with English children, the Union Jack was substituted for the American flag which appears on the correct piece for picture IX. The fact that English children do not usually salute the flag should make that part of the test harder than for American children. Healy found that of the total number of correct placings 16·93 per cent. were in this picture. (Healy, W., *Pictorial Completion Test II*, J. of App. Psych. 1921.)

TABLE V.—*Table for Scoring Healy P.C. II. Value of Pieces as placed in Pictures I to X.*

Pieces	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
1	–	–	–	–	2	–	–	–	–	*12·5*
2	0	0	1	2	–	0	0	0	0	0
3	–	–	–	–	–	–	1	*15·5*	–	–
4	–	–	–	–	0	–	–	–	–	6
5	–	–	–	–	–	–	0	0	0	–
6	0	–	–	0	–	–	–	–	–	–
7	0	0	1	2	–	0	0	0	0	0
8	*6*	–	–	2	–	–	–	–	–	–
9	–	5	0	–	0	–	–	–	–	0
10	0	–	–	1	–	–	–	–	–	–
11	1	–	–	8	–	–	–	–	–	–
12	–	0	–	–	0	–	–	–	–	1
13	–	5	0	–	3	–	–	–	–	1
14	–	–	–	–	–	–	1	6	–	–
15	–	–	1	–	–	1	0	0	0	–
16	–	–	–	–	–	–	0	0	0	–
17	–	–	–	–	–	–	1	6	–	–
18	–	–	0	–	–	*9·5*	–	0	–	–
19	–	2	–	–	0	–	–	–	–	0
20	–	–	–	–	–	–	–	–	–	–
21	–	0	–	–	1	–	–	–	–	0
22	–	–	–	–	2	–	–	–	–	6
23	1	–	–	*18*	–	–	–	–	–	–
24	–	–	–	–	0	–	–	–	–	6
25	–	–	–	–	–	–	2	0	0	–
26	–	–	0	–	–	4	0	0	0	–
27	–	5	0	–	1	–	–	–	–	0
28	–	–	0	–	–	4	0	0	0	–
29	–	–	–	–	–	–	–	–	–	0
30	2	–	–	2	–	–	–	–	–	–
31	1	–	–	8	–	–	–	–	–	–
32	–	0	–	–	*7*	–	–	–	–	0
33	–	–	–	–	–	–	1	7	–	–
34	–	–	–	–	–	–	*5·5*	0	0	–
35	–	–	*11*	–	0	0	–	–	–	0
36	–	–	1	–	–	2	0	0	0	–
37	–	0	4	–	0	0	–	–	–	0
38	–	–	–	–	–	–	–	–	–	0
39	–	–	–	–	–	–	0	0	1	–
40	–	–	–	–	–	–	–	–	–	1

TABLE V.—*continued.*

Pieces.	I.	II.	III.	IV.	V.	IV	VII.	VIII.	IX.	X.
41 ..	–	0	–	–	2	–	–	–	–	0
42 .	0	–	–	2	–	–	–	–	–	–
43 ..	–	0	–	–	2	–	–	–	–	0
44 ..	–	–	1	–	–	1	0	0	0	–
45 ..	3	–	–	2	–	–	–	–	–	–
46 ..	0	0	6	0	0	0	–	–	–	0
47 ..	–	5	0	–	1	–	–	–	–	2
48 ..	–	–	–	–	–	–	0	0	*9*	–
49 ..	–	*10*	0	–	1	–	–	–	–	2
50 ..	0	–	–	–	–	–	0	0	1	–
51 ..	0	0	1	2	–	0	0	0	0	0
52 .	1	–	–	8	–	–	–	–	–	–
53 ..	0	0	1	2	–	0	0	0	0	0
54 ..	–	–	–	–	–	–	0	0	0	–
55 ..	–	–	6	–	0	0	–	–	–	0
56 ..	–	–	–	–	–	–	2	0	0	–
57 ..	–	–	–	–	–	–	0	0	1	–
58 ..	0	0	1	2	–	0	0	0	0	0
59 ..	–	–	–	–	–	–	0	0	2	–
60 ..	–	0	2	–	0	0	–	–	–	0

Results.

(a) *Sex differences.*—There is a significant difference between the mean and median scores for boys and girls, the boys' scores being superior. (Figures 8 and 9; Tables VI and XVII.)

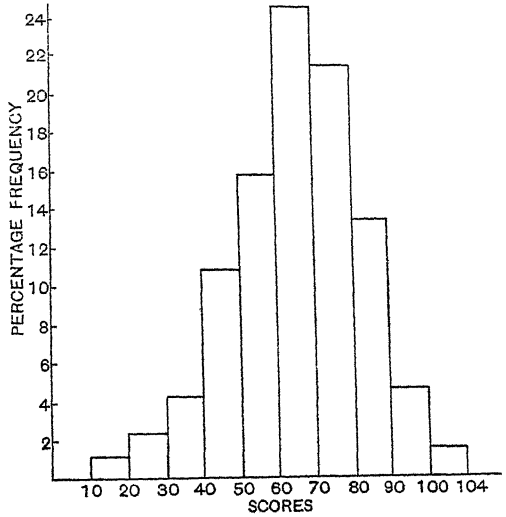

FIG. 8.—Picture completion test, II. Distribution of Scores: boys.

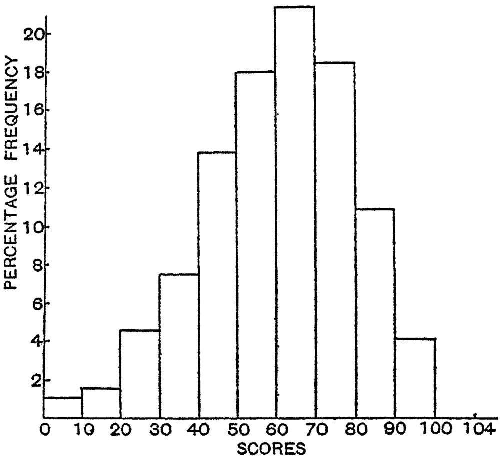

FIG. 9.—Picture completion test, II. Distribution of Scores: girls.

(b) *Range of scores.*

TABLE VI.—*Range of Scores for the Picture Completion Test.*

	No. of cases.	Median.	Quartiles.	Standard Deviation.
This group—				
Boys	300	65·5	54·5—76·5	17·4
Girls	270	61·0	48 —73·5	19·1
Gaw's group				
Boys	52	66·2	—	14·4
Girls	48	59·2	—	18·8
Healy's [1] group Both sexes	160	58	50 —69	—

(c) *Remarks.*—According to Healy's norms, a score of 59 is equivalent to a mental age of 13½; but according to Gaw, it is equivalent to a mental age of 11½. The discrepancy may be due to the combining of results for boys and girls, thus ignoring the significant difference between the means. Clearly Gaw's norms are too low for these children since 37 per cent. of our cases score 70 and over, whereas 65 and 66 are the maximum scores given in Healy's and Gaw's norms respectively, and these scores are represented as equivalent to mental ages of over 16 years.

(d) *The ability required for success in the test*:—Worthington[2] maintains that the task involves a specific rather than a general ability. She quotes Perry[1] who found that among a group of mentally deficient subjects success in this test correlated with ability in social adjustment rather than with age level.

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[1] Healy, W.: Pictorial Completion Test II. *Journal of Applied Psychology, Sept.*, 1921, pp. 225–239.

[2] Worthington, M. R.: Commonly used Performance Tests. *Journal of Applied Psychology, Vol. X*, 1926.

Although the instructions indicated that it is necessary "to study the picture," large individual differences occur with regard to the exploration of the alternative solutions. The degree of appropriateness of each picture element can only be determined by the comparison of alternatives. In this test even serious mistakes are not obvious and self-corrective as they are for example, in the Dearborn Formboard. Hence the hasty child tends to make a poor score because he fails to realise the difficulty of the problems. Herein lies part of the unique value of the test, since in the practical problems of life it is the ability to select relevant from irrelevant details, rather than to use the relevant when already selected, that is of importance. Further, the clues in this test are often details of facial expression and gesture indicating particular states of mind which are essential in the situations depicted. Thus enters a factor of "interest in people" and this may explain Perry's findings as to "social adjustment."

5.—FORMBOARD. (DEARBORN.)

Material.—The material for this test consists of a formboard measuring 11·5 in. × 13·5 in., and six different types of insets, as illustrated in the diagrams (Fig. X); also a stop watch.

Procedure.—The board is placed before the subject arranged as in the diagram for demonstration. The examiner explains to the subject that the blocks can be rearranged so as to make room for the extra square. The examiner then solves the problem, using the minimum number of moves, while the subject watches. A move is placing or trying to place a block in one of the apertures. Any attempt to place a block is counted as a move if the block actually touches the board. The board is next presented arranged for Problem A (*see* Fig. 10). The examiner says:—

> "Change these blocks so that you can find a place for the extra square (*pointing to the square*). Don't have any blocks left over, and do it in as few moves as you can, and as quickly as you can."

If not solved, the correct solution is demonstrated before going on to the next part. The board is then presented ready for problem B, the examiner telling the subject to rearrange it so as to make room for the extra squares. The board arranged for problem C is then presented, the examiner telling the subject again to make room for the extra blocks. The subject is not

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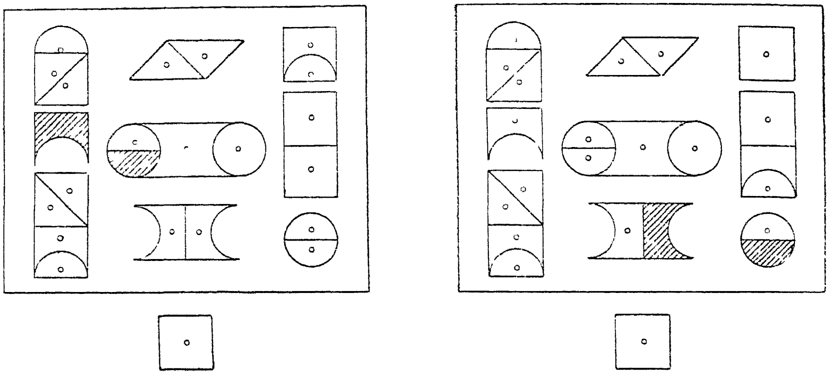
[1] Perry, Doris: "Interpretations of the reactions of the feeble-minded on the Healy Picture Construction Test II.": *Journal of Delinquency, Vol. VIII,* 1922.

Examiner.

Examiner.

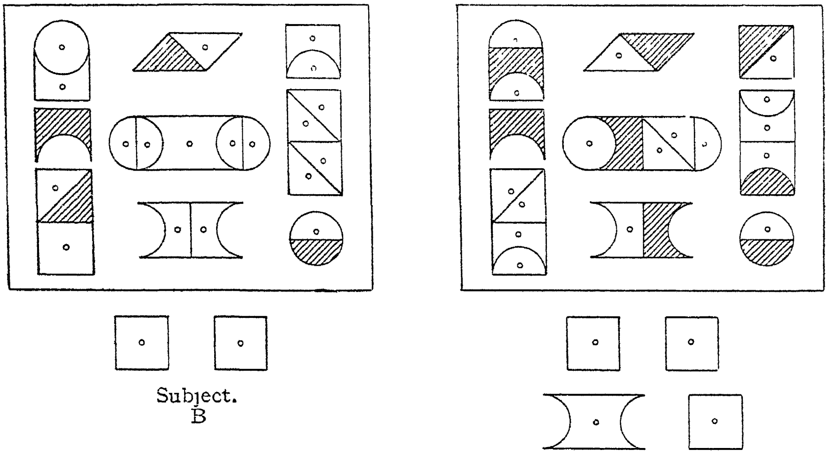


Subject.
Demonstration.

Subject.
A

Examiner.

Examiner.



Subject.
B

Examiner.

Subject.
C

FIGURE 10.

Shaded parts indicate unfilled spaces.

Demonstration and Problems A, B and C are reproduced, by permission of the publishers, from Yoakum and Yerkes; "Mental Tests in the American Army." Henry Holt & Co., New York; Sidgwick & Jackson, Ltd., London, 1920.

allowed to watch while the board is being rearranged. A cardboard screen which can be placed between the child and the examiner is useful for this test. A copy of the four accompanying diagrams can be pasted on the side of the screen facing the examiner ; with a little practice, the board can be arranged for the successive problems within 30 seconds.

Time Limit :—Problems A and B, 2 minutes ; Problem C, 3 minutes.

Scoring.—The time in seconds and the number of moves, taken for each problem separately, are recorded. If a problem is not solved within the time-limit, that part of the test is scored zero ; but if a correct solution is found the problems are scored as follows :—

TABLE VII —*Marks gained according to number of moves made. Formboard (Dearborn)*

	Problem.	Marks.				
		5	4	3	2	1
No of Moves ..	A	–	–	3	4	5–7
	B	–	–	5	6	7–10
	C	8	9	10–11	12–14	15–20

TABLE VIII.—*Marks gained according to time taken. Formboard (Dearborn).*

	Problems.	Marks				
		5	4	3	2	1
Time (in seconds)	A & B	0–10	11–20	21–40	41–70	71–120
	C	0–20	21–40	41–70	71–110	111–180

The marks for moves and for time are added for the total score.

Results.

(a) *Sex differences.*—The mean and median scores for boys are higher than those for girls and the difference is significant. (Figures 11 and 12; Tables IX and XVII.)

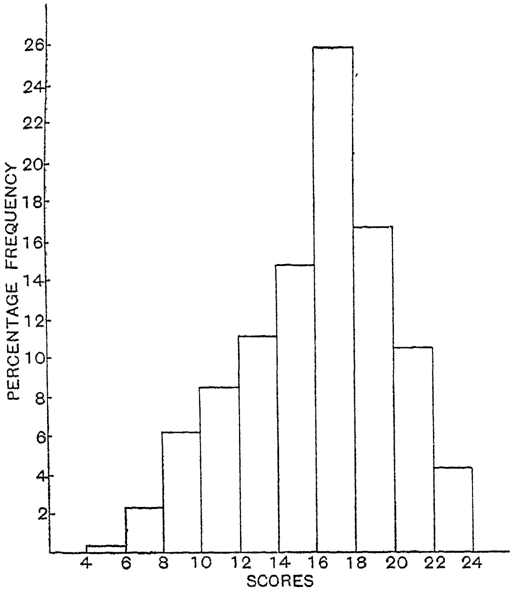


FIG. 11.—Dearborn Formboard Distribution of Scores: boys.

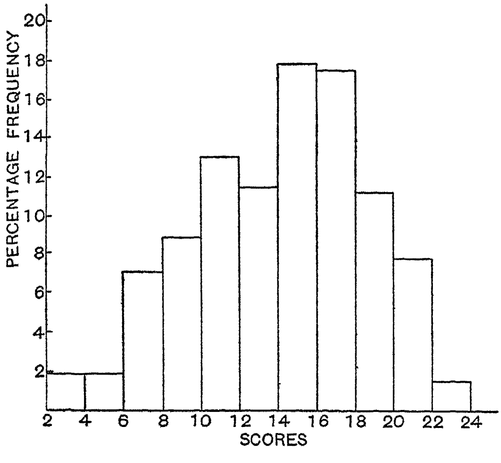


FIG. 12.—Dearborn Formboard. Distribution of Scores: girls

(b) *Range of scores.*—

TABLE IX.—*Range of Scores in the Formboard Test* (*Dearborn*).

	No. of cases.	Median.	Quartiles.	Standard Deviation.
This group—				
Boys	300	16·0	13·1–18·3	3·84
Girls	270	14·0	10·7–17·1	4·6
Gaw's group				
Boys	52	15	—	3·9
Girls	48	15·5	—	3·1

(c) *Remarks.*—According to Gaw's norms, 14·7, which is the median score for this group, is equivalent to a mental age of 10¾. Unless in this particular test the general ability (or general intelligence) which all these performance tests are supposed to measure is exceptionally overweighted by the influence of other abilities which vary far more than general ability from group to group, it is difficult to see why the results of this test, expressed as a mental age should be so different from those of other tests.

(d) *The ability required for success in the test.*—Failure seems largely due to inability to manipulate the various forms in thought before performing the actual movement. Thus a piece may be fitted into the first available space, without any forethought as to whether such a move will further the desired end. In extreme cases the attempt may be made to force pieces into spaces of quite different shape, before the error is realised.

It is interesting to compare this test with a group test of form relations, where the shapes can only be identified mentally.[1] We found a correlation of ·38 between the results of these two tests, which is higher than that between this test and any of the other tests given to the same group of (113) boys.[2] In the case of a group of 137 girls this correlation is ·47 while for a smaller group of 42 girls it is as high as ·96.

The manipulative character of the response in the Dearborn Formboard has also a temperamental aspect. The difficulty of the problems and the urge to maximum speed tend to arouse fear of failure, and this inhibits thought and prevents planning ahead. Such a state of mind seems to be relieved by action, so that haphazard moves are the result. This behaviour is often difficult to distinguish from the crude "trial and error" mode of response, for in both cases, just as in more thoughtful procedure, the moving of a piece may give a fresh combination of forms from which a solution of the problem may be more easily derived

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[1] *See* p. 35 for brief description of this group test.

[2] *See* Table XVIII, p. 37.

6—Cube Construction.

Material.—The materials for this test are three wooden blocks called models 1, 2 and 3 respectively, and the twenty-six 1-inch cubes which are necessary to construct these three models; a stop-watch is also required. Models 1 and 2 measure 1 × 3 × 3 inches and are made to represent a solid composed of nine small cubes. Model 3 is a 2-inch cube so marked as to represent a composite of 8 small cubes.

Procedure.—The examiner presents model 1 and says:—

> "You see this block. Notice that it is painted on the sides, but not on the top or the bottom , and you see these small cubes, partly painted and partly unpainted. These nine cubes can be put together so as to make one block just like this."
>
> (The examiner puts the cubes together, pointing out and commenting on the painted surfaces of each cube as he fits it in position. He then points to the block which he has assembled and says) :—
>
> "You see that I have put these cubes together to be just like this big block (*pointing to model* 1). This one I have made (*examiner picks up the nine cubes which he has assembled and holds them together in his hand as one block while he points to the four sides, top and bottom as he mentions them*) is painted on all four sides, but not on the top, and not on the bottom. You see it is just like this one (*pointing to model* 1)."
>
> The examiner then presents the same model and cubes in irregular order and says: "Now, you are to fit the cubes together so as to make a block just like this. Do it as quickly as you can and tell me when you have finished."

The examiner then times the performance and counts the number of moves.

The examiner presents model 2 and the cubes for its construction and says:—

> "Now put these cubes together so as to make one block just like this. Notice that it is painted on the edges and on the top but not on the bottom. Do it as quickly as you can and tell me when you have finished." (*Examiner points to the edges and the top and the bottom as he mentions them.*)
>
> He then presents model 3 and says: "You see this block, notice that it is not painted anywhere." (*He turns the block over and indicates that it is entirely unpainted.*)
>
> "And you see these small cubes that have three sides painted and three not painted. Now I want you to fit these eight cubes together so as to make one just like this. Remember it is not painted on the bottom, top or sides.[1] Do it as quickly as you can and tell me when you have finished."

---

[1] In practice it has been found convenient to have separate boxes for the *cubes* making up each of the three models. This not only saves time in giving the test, but avoids the possibility that the subject may be unduly assisted by watching the examiner sort the cubes for each part.

Scoring.—A record is made of the number of moves, i.e. the placings of the cubes in some position designed to complete or alter the structure. If parts of a structure are assembled separately, putting such parts together to form the structure as a whole does not count an additional move. Changing the face of a cube does not count as a move. The time in seconds taken for constructing each model is also recorded.

Time Limit (for work on each model), 2 minutes.

If the subject assembles the cubes before the time is up, spontaneous corrections are allowed, but the extra time and the additional moves are counted. Each cube changed counts one move as before. The time should be taken when the subject indicates verbally or otherwise that he has finished.

Whether the subject has finished or not, each misplaced cube is counted as three additional moves; each unassembled cube is also counted as three additional moves.[1]

No credit is allowed for time if the cubes are not all assembled. Time (if the cubes are all assembled) and the total number of moves (whether the cubes are all assembled or not) are credited as follows :—

TABLE X.—*Marks gained according to number of moves made (Cube Construction).*

	Model.	Marks.				
		5	4	3	2	1
Moves (No of)	1 2	9	10–11	12–15	16–25	26–50
	3	8	9–10	11–15	16–25	26–50

TABLE XI.—*Marks gained according to time taken (Cube Construction)*

	Model.	Marks.				
		5	4	3	2	1
Time (in seconds)	1	1–10	11–25	26–50	51–80	81–120
	2 3	1–20	21–30	31–50	51–80	81–120

The marks for moves and for time are added for the total score.

---

[1] After testing a large number we considered that a penalty of 6 for each unassembled cube was excessive in certain cases. For some children having constructed the block, destroyed it again in their persistent efforts to correct a misplaced cube. Thus, when the time limit was up, they were heavily penalised (*see* p. 31). This change in scoring, however, only affects a comparatively small number of cases.

Results.

(a) *Sex differences.*—The mean and median scores for boys are better than those for girls, the difference being significant. (Figures 13 and 14; Tables XII and XVII.)

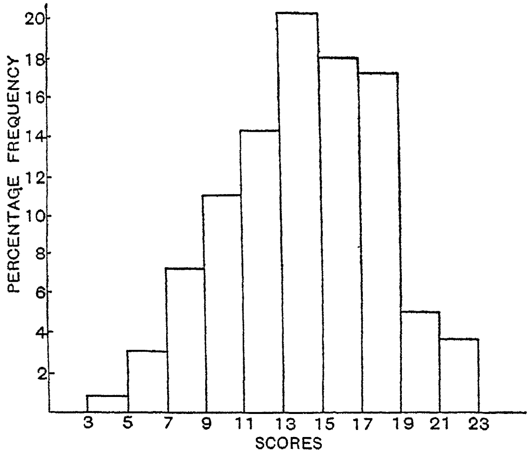

FIG. 13.—Cube construction test. Distribution of Scores: boys.

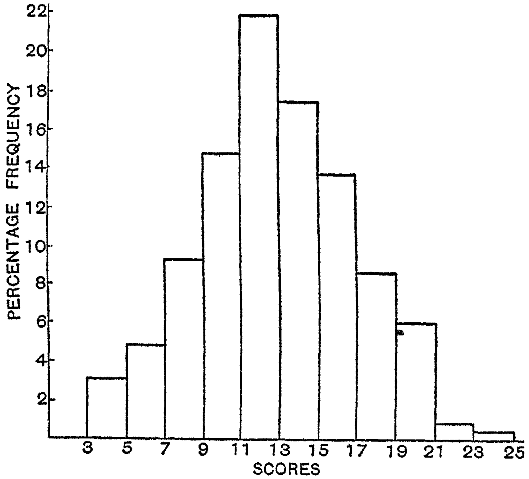

FIG. 14.—Cube construction test. Distribution of Scores. girls.

(b) *Range of scores.*—

TABLE XII.—*Range of Scores in the Cube Construction Test.*

	No. of cases.	Median.	Quartiles.	Standard. Deviation.
This group—				
Boys	300	13·9	11·1—16·7	3·9
Girls	270	12·5	9·7—15·1	4·05
Gaw's group—				
Boys	52	11	—	4·3
Girls	48	12	—	4·9

(c) *Remarks.*—Gaw's norms show a very uneven increase in score with age. There is no difference between her means for years 11 and 12, 1 mark difference between 12 and 13, and 6 marks difference between 13 and 14. No indication of any such sudden development of the ability between the ages 13 and 14 is apparent in our data.

(d) *The ability required for success in the test.*—Observation suggests that errors are due to lack of realisation of the principles on which the cubes are painted. Sometimes children will offer a model as complete in spite of a clearly visible misplaced cube. Incorrect solutions of this kind may be produced very quickly and so gain a maximum score for time. On the other hand, there are children who recognise the error and systematically search for a means of correcting it, but, owing to the time limit, may not succeed ; in which case their total score may be lower than in the case of children who make no attempt at correction. Accordingly, we thought that scoring on the basis of time might lower the discriminative value of the test, and marks were provisionally awarded on the basis of moves only. The distribution obtained, however, was not good (*see* Fig. 15), and the correlation coefficients obtained with other tests were lowered (Table XIII). It was therefore concluded that in spite of the tendency to penalise persistence and care, the combined time and moves score is the more satisfactory.

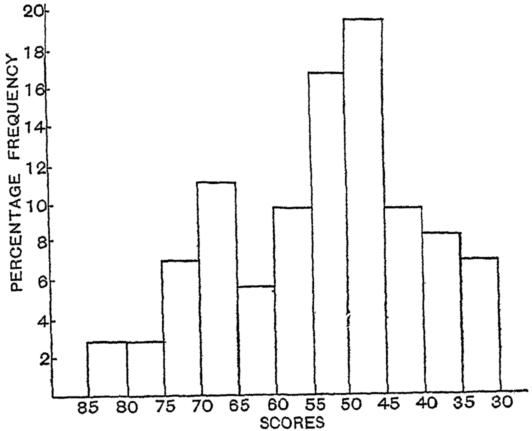

FIG. 15.—Cube construction test. Distribution of Scores on basis of Moves only.

TABLE XIII.—*Correlations between Cube Construction (as scored by two different methods) and other tests.*

	Binet.	Intelligence Group Test.	Form Relations.
Scoring by moves and time ..	·37	·44	·62
Scoring by moves only	·31	·34	·54

To sum up the general results of our studies in the above six tests, it appears that the score distributions are not in harmony with those reported by other investigators. In nearly every case the median score of our group was found to be equivalent to a mental age inconsistent with the general level of the group determined in other ways (cf. Table XIV) including an Intelligence group test.

TABLE XIV.—*Mental Ages equivalent to median scores obtained by our Group* (*From Gaw's Norms.*)

Intelligence Group Test	Maze.	Cube Imitation.	Substitution	P C II.	Cube Construction	Formboard
12½	12	13½	15	14¾	13¼	10¾

It is doubtful if we have a right to expect that the median ages for each of these *single* tests (which are *believed* to be performance tests of intelligence) should be identical with the mental ages obtained from a *series* of other tests which have been *accepted* as measurements of intelligence. In other words it is probable that factors other than "intelligence" greatly influence the results, since if the tests were all good measures of intelligence, there would be less variation from test to test than there appears to be. This raises several further points. Owing probably to their social environment the mental level of the group of children here dealt with appears to be retarded by about 1½ mental years on the evidence of tests of both the Binet and the Group type. There is no reason, however, to suppose that the group is similarly backward in respect of any abilities that may be relatively independent of "intelligence." For example, supposing manual dexterity to be independent of intelligence, since the group is probably unselected as regards manual dexterity, the median score in tests of this ability should be quite equal to the average for a fourteen year old group. In the present instance all the six tests appear to be positively related to tests of intelligence in varying degrees; accordingly their medians are variously influenced by intelligence and by special difficulties inherent in the form of the tests. The Formboard test appears relatively difficult, the Substitution test relatively easy, and yet it is hard to conceive of any special process of selection at work which would operate to produce a group of examinees specially fitted to succeed in the Substitution test and at the same time unfitted for the Formboard test.

Hence we can only conclude that the standardisation of these performance tests is likely to suffer from the peculiar difficulty that the results are influenced by specific factors which vary from age to age and from group to group in a less uniform manner than does the more general factor of intelligence.[1] As to the nature of these specific factors more will be said in Section IV when comparative studies with the results of other tests have been made.

7.—OTHER TESTS USED WITH SMALLER GROUPS

(i) *Picture Completion I (Healy).*

This test is similar in type to the Healy Picture Completion Test II.[2]

It was given to about 360 children but subsequently omitted owing to the contradictory results obtained. Many children gained lower scores in this test than in Picture Completion Test II. Worthington[3] also found that it cannot be used satisfactorily as a mental age test. Wells[4] used this test as a "shock absorber," i.e. to accustom the subject to the test situation. We found that it served this purpose very well.

(ii) *Form board (Goddard).*

The material consists of a wooden board and ten wooden blocks of various shapes which fit the recesses cut in the board. The score is the time taken to fit the blocks into the board.[5]

This test was given to a group of 259 children. The results obtained and the comparison with the published norms are shown in the following table. At the age of 13–14 success seems to depend as much on speed of movement as upon speed of perception.

TABLE XV.—*Range of Scores for Goddard Formboard.*

	No of Cases	Median.	Quartiles.	Standard Deviation.
This group— Boys .. Girls ..	259	(secs) 13	15–11	2·2
Pintner's group ..	—	12	14–11	—
Gaw's group—				
Boys	52	12·0	—	1·7
Girls	48	12·0	—	2·1

---

[1] Further evidence on this point is provided by an unpublished study of the reliability of these Performance Tests carried out by Miss M. Lichtenberger under the direction of the National Institute. The reliability coefficients vary from age to age

[2] For procedure and norms *see* Gaw, op. cit.

[3] Worthington, op. cit.

[4] Wells, F. L., "*Mental Tests in Clinical Practice*" New York. World Book Co., 1927.

[5] For detailed procedure and norms *see* Gaw, op. cit.

(iii) *Feature Profile Test.*

The material consists of pieces of wood which, when correctly put together, represent a man's face in profile. The pieces are placed before the subject who is told to put them together as quickly as he can.[1] The score is the time taken in seconds to assemble the pieces correctly. No credit is given for a partially correct solution.

This test was given to a group of 259 children but was subsequently omitted on account of the unsatisfactory distribution obtained. Since 33 per cent. of the cases scored zero, it appears that there are too many of the chance elements characteristic of so many other puzzles for the test to be satisfactory in determining mental age. The results obtained and the comparisons with other published norms are shown in the following table.

TABLE XVI.—*Range of Scores for Feature Profile Test.*

	No. of cases	Median.	Quartiles.	Standard Deviation.
This group—				
Boys	143	106	215–43	81·4
Girls	116	126	226–69	
Pintner's group ..	—	150	299–90	—
Gaw's group—				
Boys	58	79·5	—	81·1
Girls	42	72·5	—	96·3

The percentile ranks for girls and boys separately in each of the six tests above described have been collected together in Table XVII.

TABLE XVII.—*Percentile Ranks and Corresponding Scores.*

Test	Percentile.										
	0	10	20	30	40	50	60	70	80	90	100
Porteus—											
Boys .	8·4	10·8	11·5	11·9	12·2	12·4	12·7	13·0	13·3	13·6	14·0
Girls	8·0	10·2	10·9	11·3	11·7	12·1	12·5	12·9	13·3	13·7	14·0
Cube Imitation—											
Boys .. .	3·0	5·5	6·3	6·8	7·2	7·7	8·1	8·5	9·0	9·6	12·0
Girls . ..	2·0	5·4	6·2	6·7	7·1	7·5	7·9	8·4	9·0	9·9	12·0
Substitution—											
Boys .. .	159·0	122·5	109·5	103·5	98·0	93·5	88·0	83·0	77·5	71·0	50·0
Girls .. .	158·0	121·5	108·5	102·0	96·0	90·5	85·0	79·5	74·0	67·5	51·0
Picture Completion—											
Boys . .	15·0	42·5	51·5	57·5	62·0	65·5	70·0	74·5	79·5	85·5	104·0
Girls .	4·5	35·0	45·0	50·5	55·5	61·0	66·0	71·5	76·5	83·5	104·0
Formboard—											
Boys . ..	4·0	10·0	12·2	13·8	15·1	16·0	16·9	17·8	18·8	20·1	23·0
Girls . ..	2·0	7·6	9·9	11·4	12·7	14·0	15·2	16·5	17·7	19·3	23·0
Cube Construction—											
Boys . ..	3·0	8·3	10·3	11·7	12·8	13·9	15·0	16·1	17·3	18·5	22·0
Girls	3·0	7·1	9·1	10·3	11·5	12·5	13·5	14·6	15·8	17·5	24·0

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[1] For detailed procedure and norms *see* Gaw, op. cit.

8.—TESTS USED IN COMPARATIVE STUDIES.

The following are the tests that were given to the same subjects and the results of which were available for comparative studies :—

(i) *The Stanford Revision of the Binet-Simon Intelligence Scale.*

The instructions and age assignments used were those of Burt's London revision of this scale.

(ii) *Group Intelligence Test.*

This is a Group Test (No. 34) devised by the National Institute of Industrial Psychology for use with elementary school children at or near school leaving age It consists of the usual component tests, such as opposites, analogies and completion of sentences ; it also includes two tests presented pictorially.

(iii) *Immediate Visual Memory*

In this test a series of eight geometrical designs, graded in difficulty, are exposed separately for 10 seconds. The subjects are asked to reproduce each design from memory on paper immediately after its exposure. The drawings are marked for accuracy in detail and proportion, according to a fixed schedule of marks. (cf. Memory for designs test, Stanford-Binet, Year X.)

(iv) *Form Relations Test.*

This is a paper and pencil test usually given as a group test. It consists of a number of geometrical figures so drawn that in each one a portion is presented as missing. The subject is asked to choose from among a number of alternatives the " part " which belongs to each incomplete " whole." The figures are arranged in sets of five, the sets being graded in difficulty, the most difficult requiring the selection of two " parts " to complete the whole. Each set of forms is presented separately. Marks are awarded for correct identification of forms, time limits being imposed for each part of the test. (The test differs from the Formboard tests in that direct " trial and error " methods (by manipulation) are not possible.)

(v) *Mechanical Ability Test.*

This is a modification of the Stenquist individual test of mechanical ability. It consists of a series of ten familiar objects such as a bicycle bell, spring lock, etc., which have been taken to pieces and arranged conveniently into a number of component parts. The subject is allowed half-an-hour to construct the ten objects from the parts provided. Marks are awarded only for accuracy.

III.—Analysis of Results.

1.—METHODS OF COMPARISON.

In the last section we discussed the distributions of scores obtained in each of the performance tests of intelligence which we are studying. There remains the important task of comparing the results of each separate test with the others in order to discover how the abilities measured by each of them are related. As already mentioned (p. 6) this may be done in two ways—

(i) by comparing an individual's score in a given test with his scores in as many other tests as possible,

(ii) by comparing an individual's score in a given test with his efficiency and achievement in different kinds of work.

The first comparison is conveniently carried out by means of the correlation coefficients calculated between all the possible pairs of tests. (A correlation coefficient expresses in a numerical form the extent to which the scores in one test obtained by a given group of persons agree with the scores obtained by the same group of persons in another test. If the scores are proportional or if the order of merit is the same in both tests then the correlation coefficient is + 1 or approximately + 1[1]; if the order or merit is so different in the two tests that there is little or no agreement the correlation coefficient approximates to zero; if the order obtained in the first test is inverted in the second, then the coefficient is negative.)

The second comparison requires some determination (objective or otherwise) of the efficiency of the persons examined in such various kinds of work as are to be considered. In the present case we were able to obtain a measure of efficiency in occupations such as carpentry, smithing and fitting, from the estimates of instructors and from the results of examinations held during the courses of training which the persons examined were undergoing. In this comparison the examinees were not elementary children of fourteen years of age; they were apprentices attending a special technical school and they were about sixteen years of age.

It will be convenient to deal with these comparisons separately, the second being taken in §3 of Section IV.

2.—INTER-CORRELATIONS BETWEEN TESTS.

The correlation coefficients obtained by the Pearson product-moment formula for various groups of boys and girls are shown in Tables XVIII–XXI. Descriptions of the tests which have been compared in this way were given in Section II of this report. The order of the tests in the tables is as follows:—

1. Maze Test.
2. Cube Imitation Test.
3. Substitution Test.
4. Picture Completion Test.
5. Formboard Test.
6. Cube Construction Test.
7. Binet-Simon Intelligence Test.
8. Group Intelligence Test.
9. Immediate Visual Memory Test.
10. Form Relations Test.
11. Mechanical Ability Test.

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[1] According to the formula used.

TABLE XVIII.—*Inter-Correlations of Nine Tests.* [1]

(Group of 113 *boys)*

Test.	1	2	3	4	5	6	7	8	9
1. Maze	—	36	33	36	31	32	23	34	28
2 Cube Imitation	36	—	38	23	27	32	31	32	29
3 Substitution	33	38	—	33	19	32	53	47	32
4 Picture Completion	36	23	33	—	26	22	26	29	·44
5 Formboard	31	27	19	26	—	36	14	29	·38
6. Cube Construction	32	32	32	22	36	—	34	·53	46
7 Intelligence Group	23	31	53	26	14	34	—	·51	·37
8 Immediate Visual Memory	34	32	47	29	29	·53	51	—	·36
9 Form Relations	28	29	32	44	38	46	37	36	—

Probable errors of above coefficients

for r = ·53 P.E. = 046.
for r = ·14 P.E. = ·062.
when r = ·18 it exceeds 3 times its P E.

TABLE XIX.—*Inter-Correlations of Nine Tests.*

(Group of 137 *girls.)*

Test	1	2	3	4	5	6	7	8	9
1 Maze	—	35	·34	·28	14	26	·33	·39	·26
2 Cube Imitation	35	—	32	·11	20	27	44	26	·18
3 Substitution	34	32	—	32	38	35	42	37	·36
4. Picture Completion	28	11	32	—	31	·27	39	35	·31
5 Formboard	14	20	38	·31	—	·35	43	39	·47
6. Cube Construction	26	27	35	27	35	—	·44	·43	·38
7 Intelligence Group	·33	44	42	·39	43	·44	—	·40	·49
8 Immediate Visual Memory	39	26	·37	35	39	·43	·40	—	·43
9 Form Relations	·26	18	36	31	·47	38	·49	43	—

Probable errors of above coefficients

for r = ·49 P.E. = 044.
for r = 11 P E = ·057
when r = ·17 it exceeds 3 times its P E.

---

[1] The introduction of revised tests and additional tests at various stages in the experiment accounts for the differences in the number of tests compared and in the number of cases considered from table to table. The smaller groups (Tables XX and XXI) are made up of those cases among the larger groups (Tables XVIII and XIX) who received the additional tests included in Tables XX and XXI. The number of cases has also been reduced by the fact that only those could be included in any group who received the tests in the same form. These remarks apply, of course, only to the additional tests; the performance tests of intelligence remained the same throughout.

TABLE XX.—*Inter-Correlations of Eleven Tests.*
(Group of 38 *boys.)*

Test	1	2	3	4	5	6	7	8	9	10	11
1 Maze	—	31	41	40	19	23	32	23	09	24	16
2 Cube Imitation	31	—	22	21	11	·12	·35	31	·16	·08	12
3 Substitution	41	22	—	40	15	25	31	37	47	08	14
4 Picture Completion	40	·21	·40	—	30	12	32	33	31	41	·06
5 Formboard	19	11	·15	·30	—	55	03	·12	·36	49	·32
6 Cube Construction	23	12	25	12	55	—	27	27	·60	49	44
7 Stanford-Binet Intelligence	32	·35	31	·32	03	·27	—	·80	·41	24	02
8 Intelligence Group	23	31	37	33	·12	·27	80	—	·41	23	06
9 Immediate Visual Memory	09	·16	·47	·31	·36	·60	·41	41	—	·45	·37
10. Form Relations	24	08	08	41	·49	49	24	23	45	—	·37
11. Mechanical Ability	·16	·12	14	·06	44	44	02	06	·37	·37	—

Probable errors of above coefficients.

for r = 80 P E = ·039
for r = 02 P E = 109
when r = 30 it exceeds 3 times its P E.

TABLE XXI.—*Inter-Correlations of Ten Tests.*
(Group of 42 *girls.)*

Test.	1	2	3	4	5	6	7	8	9	10
1. Maze	—	53	·57	·32	·20	·32	·63	·42	·49	·16
2. Cube Imitation	53	—	·53	·20	·30	·43	·51	·52	·44	29
3 Substitution	57	·53	—	·09	·31	·35	57	·48	·29	·40
4. Picture Completion	·32	·20	·09	—	·30	33	·45	28	42	·19
5. Formboard	20	30	·31	·30	—	·45	63	·44	·60	·96
6. Cube Construction	·32	43	·35	33	·45	—	37	35	·46	·55
7. Intelligence (Stanford-Binet)	63	51	57	·45	·63	·37	—	80	·72	47
8. Intelligence Group	42	·52	·48	28	·44	·35	80	—	·66	·65
9 Immediate Visual Memory	49	·44	·29	·42	·60	·46	·72	·66	—	45
10. Form Relations	·16	·29	·40	·19	·96	·55	·47	·65	·45	—

Probable errors of above coefficients.

for r = 96 P E = ·008
for r = 09 P.E. = 103
when r = ·29 it exceeds 3 times its P E.

In order to discover how closely the abilities required in the different tests are related to one another we may examine these tables of correlation coefficients in several ways :—

(*a*) We may contrast tests which correlate comparatively highly among themselves with tests between which the correlations are low. Such comparisons may show how some of the tests depend for success upon abilities which are also required in other tests. For example, the average correlation between the Cube

Construction Test and the Formboard Test is ·43, while these and all other tests which depend upon the ability to deal with relations of shape and size seem to be more closely related to each other than to tests in which this ability does not enter. By grouping tests in this way some indication of their probable relationships is procurable.

(*b*) We may apply the partial correlation formulæ of Yule to determine whether two or more tests which appear to be influenced in varying degrees by a particular factor are equally related when the influence of this factor is kept constant for all of them. Thus, if the correlation between two tests is influenced by age we may calculate what its value would be if all the testees were of the same age. In the present case age is not a complicating factor but the same methods are applicable; for example, supposing we regard the ability measured by the intelligence group test as influencing success in the ability measured by the other tests we may calculate the correlation between these other tests independently of its influence.

(*c*) Alternatively, we may use Spearman's method to calculate the correlation between each test and the general factor "g"; then, applying Yule's formula again, we may determine the correlation between different tests when the influence of the "g" factor is held constant. In this case, however, it is necessary first of all to consider whether the Spearman criterion for divisibility into two factors (general and special) is satisfied; unless the criterion *is* satisfied the formula given by Spearman is not applicable.

The results of applying each of these methods are best discussed separately.

(a) *First Method of Analysis.*

If the correlations in Tables XVIII to XXI are grouped as in Tables XXII to XXIV some interesting differences may be observed. The tests in these tables have been grouped as follows :—

Group I—those in which the apprehension of spatial relations appears to be an important factor in success. This group includes the Formboard, Cube Construction, Immediate Visual Memory, Form Relations and Mechanical Ability Tests.

Group II—those tests in which the use of language is the most dominant feature. Such tests are the Stanford-Binet Intelligence Test and the Group Intelligence Test.

Group III—the remaining tests which do not appear to be much influenced by either the ability to deal with spatial relations or the ability to use language easily. Included in this group are the Cube Imitation, Substitution, Picture Completion and Maze Tests.

The correlations in Tables XVIII–XXI have been divided into three groups as above and the average correlations of the tests in each group with one another and with the tests of the other groups have been calculated. These are shown in Tables XXII–XXIV

TABLE XXII.—*Correlations of the Tests in Group I with one another.*

Test	1	2	3	4	5
1. Formboard	— —	36 ·35 55 ·45	29 39 36 60	38 47 49 96	— 32
2. Cube Construction	**43**	—	53 ·43 60 46	·46 38 49 ·55	·44
3 Immediate Visual Memory	**·41**	**51**	—	36 43 ·45 ·45	37
4. Form Relations . .	**·58**	**·47**	**·42**	—	37
5 Mechanical Ability .	**·32**	**44**	**37**	**·37**	—

The figures printed thus **43** are the averages of the figures in the upper half of the table

TABLE XXIII.—*Correlations between the Tests in Group I and those of Groups II and III*

Test	Stanford Binet	Group Test	Maze Test	Cube Imitation	Substitution.	Picture Completion
Formboard	03 63	·14 ·43 12 44	31 ·14 19 20	27 20 ·11 30	·19 ·38 15 31	26 31 30 30
Average	**33**	**·28**	**·21**	**22**	**26**	**·29**
Cube Construction .	27 37	34 ·44 27 35	32 26 23 32	32 27 12 43	32 35 25 ·35	22 ·27 ·12 33
Average .	**32**	**35**	**·28**	**·29**	**32**	**·24**
Immediate Visual Memory	·41 ·72	51 ·40 ·41 66	·34 ·39 09 ·49	·32 ·26 ·16 ·44	·47 37 ·47 29	29 35 31 42
Average	**·56**	**49**	**·33**	**30**	**40**	**·34**
Form Relations .. .	·24 ·47	·37 ·49 23 65	·28 26 ·24 16	29 18 08 29	32 36 08 40	44 31 41 ·19
Average .. .	**36**	**45**	**·24**	**21**	**29**	**34**
Mechanical Ability ..	·02	·06	16	·12	·14	06

TABLE XXIV.—*Correlations of the Tests in Group III with each other and with the Tests of Group II.*

Test.	Group III				Group II.	
	1	2	3	4	Stanford-Binet.	Group Test.
1. Maze..	—	36 35 ·31 53	·33 ·34 ·41 57	36 ·28 ·40 ·32	·32 63 **·48**	23 ·33 ·22 42 **·30**
2 Cube Imitation .	**39**	—	·38 ·32 ·22 ·53	·23 11 ·21 ·20	·35 ·51 **·43**	31 ·44 31 52 **·39**
3. Substitution .	**41**	**·36**	—	33 ·32 ·40 ·09	31 ·57 **·44**	52 ·42 37 ·48 **·45**
4. Picture Completion..	**·34**	**·19**	**28**	—	·45 ·32 **·39**	·26 ·39 ·33 ·28 **32**

The figures printed thus **·39** are the averages

It will be observed in these Tables (XXII–XXIV)—

1. That the inter-correlations between the spatial tests in Group I are generally higher than those between any other pairs of tests except the two linguistic tests.

2. That the Immediate Visual Memory Test is the only test in Group I which correlates more highly with the linguistic tests than with the other tests of this group.

3. That all the tests in Group III correlate on the average more highly with the linguistic than with any of the spatial tests; they also correlate more highly among themselves than with the tests of Group I.

These facts are shown even more clearly in Table XXV which gives the average of all the inter-correlations between the tests grouped as described.

TABLE XXV.—*Average Correlation between Groups of Tests.*

	Group I.	Group II.	Group III
Av. corr. of Tests in Group I with ..	·46	·38	·28
,, ,, ,, Group II ,, ..	·38	·80	·38
,, ,, ,, Group III ,, ..	·28	·38	·33

If we separate the boys and girls, the corresponding figures are :—

	Boys			Girls		
	Group I	Group II	Group III	Group I	Group II.	Group III
Av corr of Tests in Group I with	42	27	25	50	·49	·31
,, ,, ,, Group II ,,	27	·80	·33	·49	·80	·44
,, ,, ,, Group III ,,	25	33	33	31	·44	·33

It thus appears that in the case of boys the tests in Group I (spatial tests) are definitely more closely related to one another than to those of the other two groups. In the case of girls the differences between the spatial tests and the linguistic tests are very slight, but there is a marked difference between the tests of Groups I and III. It may be that, in solving the problems in which space relations enter, girls depend more upon general intelligence than do boys. Further reference will be made to these results when the second and third methods of analysis have been applied.

(b) *Second Method of Analysis.*

The second method makes use of Yule's formulæ for calculating the partial correlation coefficients when the influence of one or more variables is to be considered as held constant. The appropriate formulæ for dealing with three variables and four variables respectively are as follows :—

For three variables :—

$$r_{12\cdot3} = \frac{r_{12} - r_{13} \times r_{23}}{\sqrt{1 - r_{13}^2}\sqrt{1 - r_{23}^2}} \text{ and}$$

for four variables :—

$$r_{12\cdot34} = \frac{r_{12\cdot3} - r_{14\cdot3} \times r_{24\cdot3}}{\sqrt{1 - r_{14\ 3}^2}\sqrt{1 - r_{24\cdot3}^2}}$$

Thus $r_{12\cdot34} = \cdot31$ means that the correlation between Tests 1 and 2 amounts to ·31 when variations due to the abilities measured by the tests 3 and 4 are held constant.

We have applied this method only to a few of the variables, because the third method, in the present case, possesses certain advantages. The following tables were compiled by applying the above formulæ to some of the coefficients in Table XVIII (113 boys); the remainder can be readily calculated if desired. The variables chosen were those which, in the light of our previous analysis (pp. 39–41) seemed most likely to give useful results.

TABLE XXVI.—(*Boys*)—*Partial Correlations for the Four Variables.*

1. *Form Relations.*
2. *Cube Construction.*
3. *Formboard* (*Dearborn*).
4. *Intelligence Group Test.*

$r_{12} = \cdot46$	$r_{12\cdot3} = \cdot37$ $r_{12\ 4} = \cdot39$	$r_{12\ 34} = \cdot31$
$r_{13} = \cdot38$	$r_{13\ 2} = \cdot25$ $r_{13\ 4} = \cdot36$	$r_{13\cdot24} = \cdot27$
$r_{14} = \cdot37$	$r_{14\ 2} = \cdot26$ $r_{14\ 3} = \cdot35$	$r_{14\cdot23} = \cdot26$
$r_{23} = \cdot36$	$r_{23\ 1} = \cdot23$ $r_{23\ 4} = \cdot34$	$r_{23\ 14} = \cdot21$
$r_{24} = \cdot34$	$r_{24\ 1} = \cdot23$ $r_{24\cdot3} = \cdot31$	$r_{24\cdot13} = \cdot23$
$r_{34} = \cdot14$	$r_{34\ 1} = \cdot02$ $r_{34\ 2} = \cdot02$	$r_{34\cdot12} = -\cdot05$

$r = \cdot18 > 3 \times$ P.E.

In Table XXVI there are three tests from Group I (spatial tests) and one linguistic intelligence test. The corresponding figures for the same variables calculated from Table XIX (137 girls) are given in Table XXVII.

TABLE XXVII.—(*Girls*)—*Partial Correlations for the same Four Variables.*

$r_{12} = \cdot 38$	$r_{12\,3} = \cdot 26$ $r_{12\,4} = \cdot 21$	$r_{12\,34} = \cdot 16$
$r_{13} = \cdot 47$	$r_{13\,2} = \cdot 39$ $r_{13\,4} = \cdot 33$	$r_{13\,24} = \cdot 30$
$r_{14} = \cdot 49$	$r_{14\,2} = \cdot 39$ $r_{11\cdot 3} = \cdot 36$	$r_{14\,23} = \cdot 30$
$r_{23} = \cdot 35$	$r_{23\,1} = \cdot 21$ $r_{23\,4} = \cdot 20$	$r_{23\,11} = \cdot 14$
$r_{24} = \cdot 44$	$r_{24\,1} = \cdot 32$ $r_{24\cdot 3} = \cdot 34$	$r_{24\,13} = \cdot 28$
$r_{34} = \cdot 43$	$r_{34\cdot 1} = \cdot 26$ $r_{34\cdot 2} = \cdot 33$	$r_{34\,12} = \cdot 21$

$r = \cdot 17 > 3 \times \text{P.E.}$

The inter-correlations for girls are slightly higher than for boys, so that the figures in the third column are correspondingly different. If the partial correlations $r_{13\cdot 2}$, $r_{13\cdot 4}$ and $r_{13\cdot 24}$, $r_{23\cdot 1}$, $r_{23\cdot 4}$ and $r_{23\cdot 14}$, are compared in both Tables XXVI and XXVII, it will be seen that there is a more definite indication in the case of boys than in the case of girls that the three tests concerned with relations of form are in some way connected by an ability which is independent (or partly so) of the ability measured by the Intelligence Group Test. At the same time some other factor, intelligence perhaps, seems to be common to the variables 1, 2 and 4.

If now we take another group of variables, two from the tests in Group III and one each from the other two groups, and apply the same formulæ to the correlations of Table XVIII, we get Table XXVIII.

TABLE XXVIII.—(*Boys*)—*Partial Correlations for the Four Variables.*

1. *Immediate Visual Memory.*
2 *Substitution.*
3. *Mazes.*
4. *Intelligence Group Test*

$r_{12} = \cdot 47$	$r_{12\ 3} = \cdot 41$ $r_{12\ 4} = \cdot 27$	$r_{12\ 34} = \cdot 23$
$r_{13} = \cdot 34$	$r_{13\ 2} = \cdot 22$ $r_{13\ 4} = \cdot 26$	$r_{13\cdot 24} = \cdot 21$
$r_{14} = \cdot 51$	$r_{14\ 2} = \cdot 35$ $r_{14\ 3} = \cdot 47$	$r_{14\ 23} = \cdot 35$
$r_{23} = \cdot 33$	$r_{23\cdot 1} = \cdot 21$ $r_{23\cdot 4} = \cdot 25$	$r_{23\cdot 14} = \cdot 19$
$r_{24} = \cdot 53$	$r_{24\cdot 1} = \cdot 49$ $r_{24\ 3} = \cdot 32$	$r_{24\ 13} = \cdot 38$
$r_{34} = \cdot 23$	$r_{34\cdot 1} = \cdot 06$ $r_{34\ 2} = \cdot 07$	$r_{34\ 12} = \cdot 05$

$r = \cdot 18 > 3 \times$ P.E.

The corresponding figures for the same variables calculated from Table XIX (137 girls) are as follows :—

TABLE XXIX.—(*Girls*)—*Partial Correlations for the same Four Variables.*

$r_{12} = \cdot 37$	$r_{12\cdot 3} = \cdot 27$ $r_{12\cdot 4} = \cdot 24$	$r_{12\cdot 34} = \cdot 18$
$r_{13} = \cdot 39$	$r_{13\cdot 2} = \cdot 30$ $r_{13\cdot 4} = \cdot 30$	$r_{13\cdot 24} = \cdot 25$
$r_{14} = \cdot 40$	$r_{14\cdot 2} = \cdot 29$ $r_{14\cdot 3} = \cdot 31$	$r_{14\cdot 23} = \cdot 24$
$r_{23} = \cdot 34$	$r_{23\cdot 1} = \cdot 23$ $r_{23\cdot 4} = \cdot 23$	$r_{23\ 14} = \cdot 18$
$r_{24} = \cdot 42$	$r_{24\cdot 1} = \cdot 32$ $r_{24\cdot 3} = \cdot 35$	$r_{24\cdot 13} = \cdot 29$
$r_{34} = \cdot 33$	$r_{34\cdot 1} = \cdot 21$ $r_{34\cdot 2} = \cdot 22$	$r_{34\ 12} = \cdot 15$

$r = \cdot 17 > 3 \times$ P.E.

In this case there are no very definite indications that any pair of variables is connected by some factor independently of their relations with the other variables. There is, however, a suggestion that the Immediate Visual Memory Test (1) and the Substitution

Test (2) have more in common with the Intelligence Group Test (4) than with the Maze Test (3), a possibility to which the test groupings of the first method of analysis (p. 41) also pointed.

Finally, taking three of the tests in Group III and the Intelligence Group Test we obtain Tables XXX (boys) and XXXI (girls) by the same methods.

TABLE XXX.—(*Boys*)—*Partial Correlations for the Four Variables.*

1. *Picture Completion.*
2. *Mazes.*
3. *Cube Imitation.*
4. *Intelligence Group Test.*

$r_{12} = \cdot36$	$r_{12\cdot3} = \cdot31$ $r_{12\ 4} = \cdot32$	$r_{12\ 31} = \cdot29$
$r_{13} = \cdot23$	$r_{13\ 2} = \cdot12$ $r_{13\cdot4} = \cdot16$	$r_{13\ 24} = \cdot07$
$r_{14} = \cdot26$	$r_{14\ 2} = \cdot20$ $r_{14\ 3} = \cdot20$	$r_{14\ 24} = \cdot17$
$r_{23} = \cdot36$	$r_{23\ 1} = \cdot31$ $r_{23\cdot4} = \cdot31$	$r_{23\cdot14} = \cdot28$
$r_{24} = \cdot23$	$r_{24\cdot1} = \cdot15$ $r_{24\ 3} = \cdot14$	$r_{24\cdot13} = \cdot07$
$r_{34} = \cdot31$	$r_{34\cdot1} = \cdot27$ $r_{34\cdot2} = \cdot25$	$r_{34\cdot12} = \cdot28$

$r = \cdot18 > 3 \times$ P.E.

The corresponding figures for the same variables from Table XIX (137 girls) are shown in Table XXXI.

TABLE XXXI.—(*Girls*).

$r_{12} = \cdot28$	$r_{12\cdot3} = \cdot26$ $r_{12\cdot4} = \cdot17$	$r_{12\cdot34} = \cdot20$
$r_{13} = \cdot11$	$r_{13\cdot2} = \cdot013$ $r_{13\cdot4} = \cdot075$	$r_{13\cdot24} = -\cdot12$
$r_{14} = \cdot39$	$r_{14\cdot2} = \cdot33$ $r_{14\ 3} = \cdot38$	$r_{14\cdot23} = \cdot35$
$r_{23} = \cdot35$	$r_{23\cdot1} = \cdot34$ $r_{23\cdot4} = \cdot24$	$r_{23\cdot14} = \cdot27$
$r_{24} = \cdot33$	$r_{24\cdot1} = \cdot25$ $r_{24\cdot3} = \cdot21$	$r_{24\cdot13} = \cdot12$
$r_{34} = \cdot44$	$r_{34\cdot1} = \cdot44$ $r_{34\cdot2} = \cdot37$	$r_{34\cdot12} = \cdot39$

$r = \cdot17 > 3 \times$ P.E.

It will be observed that there is a considerable degree of agreement between Tables XXX (boys) and XXXI (girls). There appears to be a connection between the Picture Completion Test (1) and the Intelligence Group Test (4) which is independent of the Maze (2) and Cube Imitation Tests (3). Similarly the Picture Completion and the Maze Tests seem to be independently related.

Other comparisons might be made, but the interpretation of the above tables depends greatly upon the complexity of the variables under consideration, and when these are composed of different factors in unknown proportions it becomes impossible to draw definite conclusions. Consider, for example, the ability measured by the Intelligence Group Test. Since it correlates satisfactorily with Stanford-Binet and with teachers' estimates of intelligence, we may regard it as a measure of general intelligence, albeit not a perfect one. What then do the performance tests measure? Why are their correlations with intelligence as measured by the group test comparatively low?

One explanation is that while the performance tests require intelligence in their solution they also depend for success largely upon specific abilities peculiar to each test. It is possible that some of these specific abilities are related; for example, all the tests concerned with relations of form which we have discussed seem to show some inter-connection which is independent of the ability measured by the Intelligence Group Test. On the other hand, it may be the case that the Intelligence Group Test does not give a sufficiently complete measure of general intelligence (regarded as a general ability which influences all kinds of activities and which therefore may be supposed to account for the correlations obtained between the various tests we are considering). If so, then the partial coefficients in the above tables may merely represent the effect of different samples of the "unmeasured" portion of this general ability.

Another explanation sometimes put forward to account for the low correlations between performance tests and the verbal type of intelligence test is that, while both tests measure general intelligence, this ability is expressed in different ways. The components of the group test collectively are also said to be a measure of two abilities, one being general intelligence, common to all tests, the other an ability to deal with words and verbal data generally; the performance tests, on the other hand, are to be looked upon as measures of general intelligence combined with an ability to deal with concrete objects and situations. Because these two "group abilities"—verbal and non-verbal—are unlike, it is argued that the correlation between tests in which they function tends to be low. But the evidence in support of this view is not very strong.[1]

Be that as it may, the evidence to be obtained from the application of the partial correlation formulæ to the "raw" coefficients is not of much value in throwing light upon this particular problem. It may, however, be said that if there were a non-verbal factor connecting *all* the performance tests under consideration we should expect their inter-correlations to be rather higher than they are, and a corresponding reduction in the partial correlations of the second order to occur when one or other of the "non-verbal" tests is held constant.

(c) *Third Method of Analysis*

The third method of analysis is based upon Spearman's Two-factor theory which is now so well known that only a brief summary of its main features need be given here.

(i) *The Two-factor theory*—It has been found empirically that some tests of mental abilities give results which are closely related to each other, in that the extent of a person's success in one of these tests may be used to predict his probable success in the others. Such tests are the well-known tests of comprehending instructions, giving opposites, analogies and solving reasoning problems. On the other hand, there are other tests in which a high score may be no indication of probable success in other activities. Thus the ability to discriminate small differences in the pitch of sounds or in the quality of touch sensations bears no relation to the ability to complete satisfactorily an unfinished sentence or to comprehend a complex problem. Each test of the former type may be regarded as one of a series linked by a single general ability or intelligence, while the latter give information concerning special abilities which operate only within a limited field.

This distinction is useful, although in practice it is seldom possible to separate abilities into two such entirely distinct types. There are few processes that do not seem to possess some specific characteristics peculiar to themselves. This has led Spearman to the formulation of his Two-factor theory, on which every mental activity depends upon the operation of two factors—the factor " g " which enters into all activities in greater or less degree, and the factor " s " which is different for every activity and whose importance in any activity is inversely proportional to that of the " g " factor.

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[1] F. Gaw in an unpublished thesis discusses the results obtained from a variety of "non-verbal" tests including those for manual dexterity and mechanical ability. Although she found no group factor of non-verbal ability she was inclined to believe that verbal and non-verbal factors do exist. C. M. Davey ("A comparison of group verbal and pictorial tests of intelligence." *Brit. J. of Psych. XVII*, 1926) also states that she found no difference between intelligence tests presented verbally and those of similar content presented in pictorial form. She concludes that there is no group factor of "verbality."

There has been considerable discussion as to whether, in addition to the universal " g " factor, there may not be " group " factors linking some of the special "s" factors together. Spearman has lately re-stated his theory and described its experimental bases[1] at some length. He declares that the " group " factors occur only over a very narrow range, the perception of spatial relations being cited as an example, but that " overlap " of specific abilities may occur when the activities to be compared are very similar. He finds, however, no group factor corresponding to the " faculty " of memory or of attention ; and he is disposed to regard the whole of the correlation which may be found between two variables as due to the " g " factor which they share in common. In other words, on his view practically all the " s " factors are entirely uncorrelated, and the explanation of any correlation other than that due to " g " will generally be found in the inevitable errors of measurement, though if the tasks are sufficiently alike, overlap of specific factors will occur to cause some correlation independent of " g."

(ii) *Application of Spearman's Method of Analysis to the data obtained in this experiment.*—For this purpose it will be more convenient to arrange the tables of coefficients in hierarchical order, i.e. according to the order of the average of the correlations in each column. This order is shown in Tables XXXII—XXXV.

TABLE XXXII.—*Group of* 113 *boys* (*age* 13 *years* 10 *months*).

Variable.	1	2	3	4	5	6	7	8	9
1. Imm. Visual Memory Test .. 1	—	·47	·36	·53	·51	·34	·32	·29	·29
2. Substitution Test 2	·47	—	·32	·32	·53	·33	38	·33	·19
3. Form Relations Test 3	·36	·32	—	·46	·37	·28	·29	·44	·38
4. Cube Construction Test .. 4	·53	·32	·46	—	·34	·32	·32	·22	·36
5. Intelligence Group Test .. 5	·51	·53	·37	·34	—	·23	·31	·26	·14
6. Mazes Test (Porteus) 6	·34	·33	·28	·32	·23	—	·36	·36	·31
7. Cube Imitation Test 7	·32	·38	29	·32	·31	·36	—	·23	·27
8. Picture Completion Test .. 8	·29	·33	·44	·22	·26	·36	·23	—	·26
9. Formboard Test (Dearborn) . 9	·29	·19	·38	·36	·14	·31	·27	·26	—

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[1] Spearman, C.: " *The Abilities of Man,*" London, Macmillan & Co.

TABLE XXXIII.—137 *girls* (*age* 13 *years* 10 *months*).

Variable.	1	2	3	4	5	6	7	8	9
1. Intelligence Group Test 1	—	·40	·49	·42	44	·43	33	·39	·44
2. Imm. Visual Memory Test 2	·40	—	·43	37	·43	39	·39	35	26
3. Form Relations Test .. 3	49	43	—	·36	·38	·47	26	31	·18
4. Substitution Test 4	42	37	36	—	35	38	34	32	32
5. Cube Construction Test . 5	44	·43	·38	35	—	35	26	27	27
6. Formboard Test (Dearborn) .. 6	43	·39	47	·38	35	—	14	31	20
7. Mazes Test (Porteus) .. 7	33	39	26	·34	26	·14	—	28	·35
8. Picture Completion Test . 8	·39	35	31	·32	·27	31	·28	—	·11
9. Cube Imitation Test 9	44	26	18	32	27	·20	·35	·11	—

TABLE XXXIV.—38 *boys* (*age* 13 *years* 10 *months*).

Variable.	1	2	3	4	5	6	7	8	9	10	11
1 Imm Visual Memory Test 1	—	60	41	·45	·41	31	·47	36	·09	37	·16
2 Cube Construction Test . 2	60	—	27	·49	27	·12	·25	55	23	·44	12
3. Intelligence Group Test 3	·41	27	—	23	80	·33	37	12	23	06	31
4. Form Relations Test . 4	·45	49	23	—	·24	·41	08	49	24	37	08
5. Stanford-Binet Test . 5	·41	27	80	24	—	32	·31	03	·32	·02	·35
6. Picture Completion Test 6	31	·12	33	·41	32	—	·40	·30	·40	06	·21
7. Substitution Test .. 7	·47	25	·37	08	31	·40	—	·15	·41	·14	·22
8. Formboard Test (Dearborn) 8	·36	55	·12	·49	·03	·30	·15	—	·19	32	·11
9 Mazes Test (Porteus) .. 9	·09	23	23	·24	·32	40	·41	·19	—	·16	·31
10. Mechanical Ability Test 10	·37	44	·06	·37	— 02	·06	·14	32	·16	—	·12
11. Cube Imitation Test .11	·16	12	31	08	35	·21	22	11	31	12	—

TABLE XXXV.—42 *girls* (*age* 13 *years* 10 *months*).

Variable.	1	2	3	4	5	6	7	8	9	10
1. Stanford-Binet Test 1	—	·80	·72	·63	·47	·51	·63	·37	57	·45
2. Intelligence Group Test . .. 2	·80	—	·66	·44	·65	·52	·42	·35	·48	·28
3. Imm Visual Memory Test .. 3	·72	66	—	·60	·45	·44	·49	·46	·29	·42
4. Formboard Test (Dearborn) . 4	63	·44	·60	—	96	30	·20	·45	·31	·30
5 Form Relations Test .. . 5	·47	·65	·45	·96	—	29	·16	·55	·40	·19
6. Cube Imitation Test . .. 6	·51	·52	·44	·30	·29	—	·53	·43	·53	·20
7. Mazes Test (Porteus) 7	63	·42	·49	·20	·16	·53	—	·32	·57	·32
8. Cube Construction Test . .. 8	·37	·35	·46	·45	·55	·43	·32	—	·35	·33
9. Substitution Test 9	·57	·48	·29	·31	·40	·53	·57	·35	—	·09
10. Picture Completion Test 10	·45	·28	·42	·30	·19	·20	32	·33	·09	—

Spearman states that the criterion determining whether or not the abilities which enter into any table of correlations are divisible into " g " and a number of uncorrelated " s " factors is the tetrad difference equation F = 0. The tetrad, F, is the difference between any two pairs of products obtained from multiplying diagonally opposed quantities in the table of coefficients. Thus the coefficients in Table XXXII, showing the relation between the Cube Construction Test, the Intelligence Group Test, the Maze Test and the Formboard Test, are as follows :—

	Mazes.	*Formboard.*
Cube Construction	·32	·36
Intelligence Group Test	·23	·14

$$\begin{aligned} \text{Whence } F &= (\cdot32 \times \cdot14) - (\cdot36 \times \cdot23) \\ &= \cdot0488 - \cdot0828 \\ &= \cdot0380 \end{aligned}$$

In a perfectly measured group all the tetrad differences should be zero for the criterion to be satisfied. But since it is impossible to obtain perfect measurements in practice, the tetrad differences should accordingly be distributed in the "normal" manner about the zero value. If the distribution curve is approximately of the "normal" form and if none of the tetrad differences exceed five times their probable error, then according to Spearman, it may be considered as proved that the inter-correlations of the variables are due entirely to the factor "g" which they all have in common.

It may be mentioned, however, that there is considerable difference of opinion among statisticians as to the adequacy of the mathematical treatment upon which this conclusion is based, and so far the theory cannot be considered to be completely worked out. In particular, Spearman has given no proof that the distribution of tetrad differences for sampling errors should follow a normal curve. Pearson and Moul[1] have shown that the full formula for the mean square tetrad is of great complexity and criticise some of Spearman's formulæ for this constant. The proof of the formula given below has not to our knowledge yet been published. Hence the conclusions which depend upon the results of the analysis in this section cannot be accepted without reservation. The results are, however, given for future reference when the theory has been more fully developed.

The formula for the probable error of the tetrad differences calculated from a table of coefficients is given by Spearman as—

$$\frac{1\cdot349}{\sqrt{N}} \times \left[r^2(1-r)^2 + (1-R)s^2\right]^{\frac{1}{2}}$$

$$\text{where } R = 3r\,\frac{n-4}{n-2} - 2r^2\,\frac{n-6}{n-2}$$

$N =$ Number of cases.
$n =$ Number of variables.
$r =$ Average inter-correlation for the whole of the variables.
$s^2 =$ Mean of the squared deviations of the separate coefficients from the mean value r.

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[1] Pearson and Moul (*Biom XIX*, *Dec.* 1927, *pp.* 246–291.)

The results of applying this criterion to the figures for the boys are shown in Fig. 16[1].

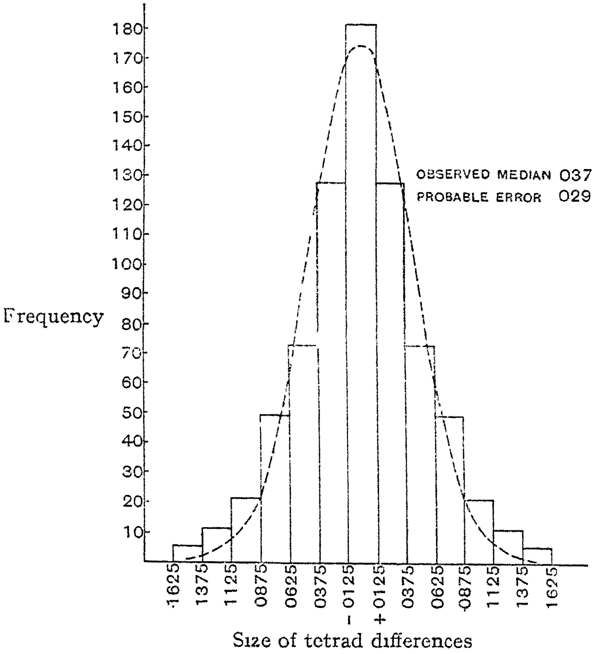


FIG. 16—Distribution of tetrad differences, calculated from Table XVIII (113 boys).

Since eight tetrad differences exceed five times the P.E. (5 × P.E. = ·1455) the criterion is not perfectly satisfied. The largest tetrad differences arise from the following combinations of tests :—

	Substitution.	*Formboard.*	
Cube Construction test ..	·32	·36	F = ·1460
Intelligence group test ..	·53	·14	

	Substitution.	*Formboard*	
Form Relations test ..	·32	·38	F = ·1566
Intelligence group test ..	·53	·14	

	Substitution.	*Picture Completion.*	
Form Relations test ..	·32	·44	F = ·1500
Intelligence group test ..	·53	·26	

	Immediate Memory.	*Picture Completion.*	
Form Relations test ..	·36	·44	F = ·1540
Cube Construction test ..	·53	·22	

---

[1] The distributions shown in Figs. 16–18, are also given in tabular form in the Appendix (p. 70).

	Immediate Memory.	Formboard.	
Form Relations test ..	·36	·38	F = ·1434
Intelligence group test ..	·51	·14	

It will be observed that the Form Relations test and the Intelligence group test each enter into four out of five of the above combinations. Both these tests were given in " group " form, and it is possible that among the boys larger errors are caused thereby. But it is difficult to see why such a result should be confined to so small a number of test combinations

If we leave out either of the two tests (Form Relations or Intelligence group test), we shall obtain a table of correlations giving only *two* tetrad differences which exceed five times their probable error, so that, *as far as the performance tests which we are here considering are concerned*, Spearman's theory that there is a factor common to the tests appears to be confirmed.

Leaving out the Intelligence group test from Table XXXII, we get a table of correlations in which there are only two tetrad differences in excess of five times the P.E. If these be regarded as due to some error of measurement and not to any high intercorrelation between several variables, the following formula may be applied :—

$$r_{ag} = \sqrt{\frac{A^2 - A'}{T - 2A}}$$

where r = the correlation between the ability " a " and " g."
A = the sum of the correlations of the test of ability " a " with all the other tests.
A′ = the sum of the squares of these correlations.
T = the sum of the correlations in the whole table.

This is Spearman's formula for calculating the correlation between each test and the common factor " g " when the tetrad difference criterion is satisfied.[1] The results obtained from its application to the coefficients of eight variables abstracted from Table XXXII are given below (Table XXXVI)

TABLE XXXVI.—*Correlation of each test with "g"* (113 *boys*) (*derived from Table XXXII*).

Immediate Visual Memory	·65	Mazes	·57
Form Relations ..	·63	Cube Imitation ..	·53
Cube Construction ..	·63	Picture Completion ..	·52
Substitution	·58	Formboard	·50

---

[1] Spearman, C., op. cit. N.B.—The formula is not applicable to Table XXXII as it stands, since the formula is based upon the assumption that the correlation between the specific factors is zero.

Using the same partial correlation formula as before, we can now find the correlations between all the possible pairs of variables holding " g " constant. They are as follows :—

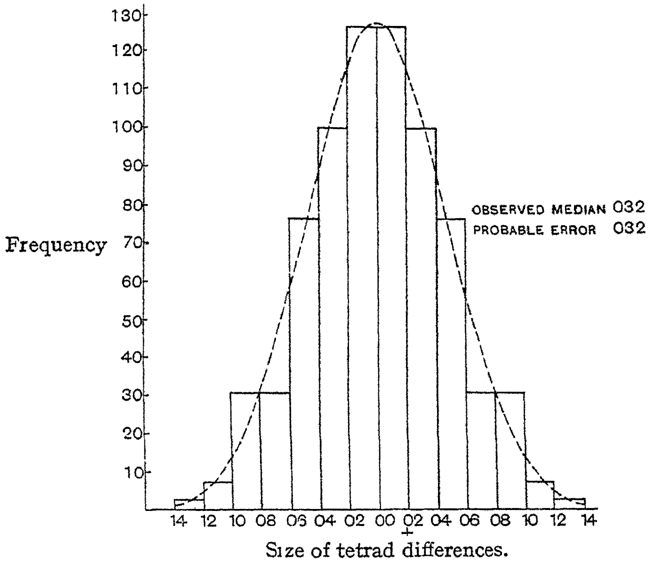
TABLE XXXVII — *Inter-correlations for " g " constant* (113 *boys*).

Test.	1	2	3	4	5	6	7	8
1. Immediate Visual Memory . 1	—	– 12	**·18**	07	–·05	– 08	– 10	–·05
2 Form Relations . 2	– 12	—	·10	–·12	–·09	– 06	**18**	13
3 Cube Construction 3	**·18**	10	—	–·12	– 03	– 02	–·15	·10
4 Substitution .. 4	07	– 12	– 12	—	00	·08	·01	–·10
5 Maze (Porteus) . 5	– 05	– 09	– 03	00	—	·10	·10	·08
6 Cube Imitation . 6	– 08	–·06	– 02	08	10	—	–·05	·04
7. Picture Completion . 7	–·10	**18**	–·15	01	·10	– 05	—	·04
8 Formboard (Dearborn) . 8	– 05	13	10	–·10	08	04	·04	—

Correlations which are large enough to be significant are printed thus **·18**, the criterion being that they are at least three times their probable error. (When r = ·18 it is > × P.E.).

It will be observed that all the correlations except two have been reduced to insignificance. Theoretically if the hypothesis of uncorrelated " s " factors were correct, all the correlations in the table should disappear (or become negligible) when " g " is held constant. The coefficients which remain are certainly not large, yet in a table of this size it is unlikely that two such coefficients can be due to chance. We might reasonably suppose that capacity to deal with " form relations " assists in " completing pictures " and that " immediate visual memory " assists " cube construction," but in view of the results obtained from applying this method to Table XXXIII which appear in Fig. 17, it seems hardly necessary to press these somewhat speculative explanations.

The results of applying this method to the figures for the girls (Table XXXIII) are given below :—



No tetrad difference is larger than 5 × P.E. (= ·162). Hence the criterion is satisfied, and according to Spearman's view the presence of a general factor is established.

It will be observed that the agreement between the distribution of tetrad differences and that which might be expected if they were distributed according to the "normal curve of error" is a close one. Hence Spearman's theorem, that the tetrad differences for dissimilar abilities are of just the magnitude that must be attributed merely and solely to the errors of sampling, is here strikingly corroborated.

This result may be taken to confirm the view expressed on p. 52 that the slight lack of agreement in the case of the boys is accidental.

The correlations with "g" calculated by the same method as before are as follows :—

TABLE XXXVIII.—*Correlations with "g" calculated from Table XXXIII* (137 *girls*).

Test.	*Correlations with "g."*
Intelligence group	·74
Immediate Visual Memory	·66
Form Relations	·62
Substitution	·62
Cube Construction	·51
Formboard (Dearborn)	·56
Maze (Porteus)	·50
Picture Completion	·49
Cube Imitation	·43

From these figures the correlations for "g" constant were calculated.

TABLE XXXIX.—*Inter-correlations for "g" constant from Table XXXIII* (137 *girls*).

Test	1	2	3	4	5	6	7	8	9
Intelligence Group .. 1	—	— **18**	·06	— 08	·10	·04	—·07	05	20
Immediate Visual Memory 2	—·**18**	—	03	—·07	·14	03	·09	05	— 03
Form Relation 3	·06	·03	—	—·03	·09	·**19**	—·07	02	—·13
Substitution .. 4	—·08	—·07	—·03	—	·05	·05	·04	03	·07
Cube Construction .. 5	·10	·14	·09	·05	—	·08	04	·03	07
Formboard (Dearborn) .. 6	04	·03	**19**	·05	·08	—	—·**20**	06	·05
Maze (Porteus) 7	—·07	·09	—·07	·04	·04	— **20**	—	·04	·17
Picture Completion .. 8	·05	·05	·02	·03	·03	·06	·04	—	—·13
Cube Imitation 9	—·**20**	—·03	—·13	07	·07	·05	·17	—·13	—

(When r = ·17 it is > 3 × P.E.).

Here there are very few coefficients of a magnitude sufficient to warrant the belief that they are due to some factor other than the unavoidable errors of measurement. It will be noted that these larger "residual" specific correlations do not occur between the same tests for girls and boys. Whence we may conclude that unless the abilities required are differently employed by boys and girls (which may of course be the case), the differences are due to a few rather large errors of measurements.

The same method of analysis was not applicable to the figures obtained from the smaller groups (Tables XXXIV and XXXV). It was found that the tetrad difference criterion was not satisfied by either of these tables; consequently the formula for calculating r_{ag} could not be used. The distribution of tetrad differences for 42 girls (calculated from Table XXXV) is shown in Fig. 18. It will be observed that a considerable number of tetrad differences fall outside the limits of five times the probable error

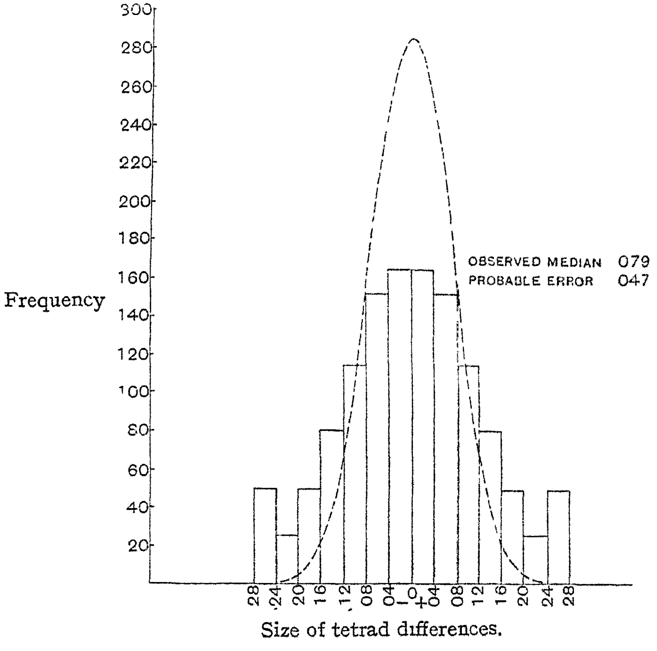


FIG. 18.—Distribution of tetrad differences, calculated from Table XXI.

It is curious that both for boys and for girls the criterion should be almost perfectly satisfied by the coefficients from the larger group of cases but not by those from the smaller group. Thomson has suggested that the results obtained by applying the tetrad difference criterion to groups of less than 60 cases are not reliable.[1] Possibly, in the present instance, this may account for the different results obtained from the two smaller groups. On the other hand, there are several very large coefficients which cannot be regarded as arising in any accidental manner from the smallness of the groups under consideration (numbering 37 and 42 respectively). For example, the correlation of ·80 between the Intelligence group test and the Stanford-Binet test and that of ·96 between the Dearborn Formboard test and the Form Relations test are large enough to suggest that factors other than "g" are operative. In both cases there is a similarity between the material used in these pairs of tests which supports the view that in addition to that due to "g" some correlation due to "overlap" of the specific factors may also occur; such a factor as "schooling" or verbal ability might, for example, somewhat magnify the correlation between the Binet test and the Intelligence group test.

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[1] Thomson, G H.: "The Tetrad difference Criterion," *B. J. Psych, Vol. XVII, Part 3*, 1927

While we are considering the question of specific correlations, the results of applying Spearman's test for specific correlation[1] to some of the coefficients of Tables XXXII (boys) and XXXIII (girls) may be mentioned.

The two tests specially considered were those of the Formboard and the Form Relations. By taking two pools of tests from the rest of the Table XXXIII we get:—

$$r_{gagb} = \cdot 64$$
$$r_{ga \cdot \mathrm{Fbd}} = \cdot 433$$
$$r_{gb \cdot \mathrm{FR}} = \cdot 474$$

whence

	Form Relations.	g pool_a	
Formboard	·47	·433	F = ·096
g pool_b	·474	·64	

The P.E. of F = ·0288.

F is just greater than 3 times its P.E. Hence in the case of girls it is just possible that specific correlation exists between these two tests.

A similar calculation for Table XXXII gives:—

F = ·071 P.E. of F = ·0316.

so that F is just greater than twice its P.E. In this case the evidence of specific correlation is lacking.

On the whole, therefore, the proof of specific correlation between the Formboard and the Form Relations group tests is not entirely conclusive; both these large tetrad differences may be due to chance.

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[1] Spearman, C.: "*Abilities of Man,*" Appendix IV, §9.

IV.—General Conclusions.

We have now the results of applying three different methods of analysis to the tables of correlation coefficients and the general conclusions to be drawn from them must next receive attention.

The conclusions may be grouped conveniently under three heads :—

1. The abilities measured by the separate tests.
2. The value of the tests as measures of " g."
3. The use of Performance Tests of Intelligence in Vocational Guidance.

1.—THE. ABILITIES MEASURED BY THE SEPARATE TESTS.

The light thrown on the nature of the separate tests by the figures given in the last section may be summarised as follows :—

(i) *The Maze Test* (*Porteus*).

Whatever specific correlations we may suggest from an examination of the partial correlations in Tables XXVIII to XXXI, it is clear that when the same data are treated by the Spearman method the connections between the Maze test and other tests appear to be due to the general factor " g " (Tables XXXVII and XXXIX). In other words, according to Spearman, the Maze test measures abilities that are independent of the other tests, except as regards "g." Burt refers to its use for detecting " verbalists," those whose high score in tests of a linguistic nature overestimates their true mental age, owing to the fact that they possess a special verbal ability. Our results partly justify such a use in that the high correlation which exists between the Intelligence group test and the Stanford-Binet test suggest a special ability connected with language, especially since the correlation of either test with " g " is not very high. On the other hand the correlation of the Maze test with " g " is considerably less, (Tables XXXVI and XXXVIII).

Hence (although the available methods of analysis are not wholly satisfactory), it seems that this test may be regarded as in part a measure of a special ability which is not directly connected with any of the abilities measured by the other tests mentioned and in part a measure of " g." Observations confirm Burt's and Porteus's suggestions that success is also dependent on qualities of an emotional nature connected with " lack of planning capacity."

(ii) *Cube Imitation Test* (*Knox*).

As in the case of the Maze test, the connection between this and other performance tests seems to be due to the influence of the general factor " g," but the correlation with " g " is lower than that for the Maze test. It may be concluded therefore that the type of memory involved in this test is a special ability unconnected, for example, with that required in Immediate Visual Memory.

Hence it is of little use alone as a supplementary intelligence test, at any rate at school-leaving age, and should be used chiefly when measurement of such a specific type of memory is required. The correlation with "g" is slightly higher for boys than for girls, but in neither case does it appear high enough to justify the use of the test *solely* for measuring mental age level A similar conclusion was reached by Worthington,[1] who gave this test to a group whose ages ranged from 5 to 16 years.

(iii) *Substitution Test* (*Woodworth and Wells*)

It is observable in Tables XXIII and XXIV that the correlation between this test and the linguistic tests of Group II is higher than any of the other correlations in which the Substitution test enters (although its correlations with the Maze test and with the Immediate Visual Memory test are almost as high). This we might expect from the nature of the test.

Using the Spearman method, however, the correlation between this and other performance tests appears to be due to the "g" factor, with which the correlation is fairly high. From Figure XVI it appears that there are eight tetrad differences exceeding five times the probable error. In three of these the Substitution and the Intelligence group tests are two of the five tests involved. It is possible, therefore, that some common ability exists which is a factor in success in both these tests. It is difficult, however, to deduce its nature from the form and content of the two tests. In the Substitution test speed is a very important factor. In the Intelligence group test it has also an effect, but this is less marked. Substitution demands pencil work, is planned as a group test, and is eminently a test of learning. Thus, it is possibly connected with the more special scholastic ability which appears to affect the ordinary group test. Whether the connection be accidental or not, the use of "substitution" as part of an intelligence scale would be justified on the ground of its correlation with "g" alone.

In the case of girls the correlation with "g" is practically the same as that for boys, but there are no significant tetrad differences. There is apparently no need for a different use of the test for boys and girls.

(iv) *Picture Completion Test II* (*Healy*).

If the results obtained with this test are treated by the Spearman method, the correlation with "g" works out rather low. Considering this, and the fact that there appears to be no consistent correlation with most of the other tests, we may conclude that this test measures a special ability—perhaps connected with form or space relations. From its form and content it is likely to be useful in connection with predicting ability in certain manual occupations. The only significant correlation, however, with trade proficiency so far obtained relates to the work of apprentice smiths (*see* p. 63); but what the basis of this relation may be it is at present difficult to say.

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[1] Worthington, op. cit.

In the case of girls, no special connection with any of the other tests is shown (except the Intelligence test). The correlation with " g " is, however, slightly smaller than in the case of the boys.

(v) *Formboard Test* (*Dearborn*).

The first method of analysis as well as the partial correlation method (Tables XXVI and XXVII) both suggest a connection between this test, the Cube Construction and the Form Relations tests. The results of applying the Spearman method, however, are somewhat contradictory. The correlation with " g " is low, and since the tetrad difference criterion is satisfied we may presume that the " s " factors are uncorrelated. But this test enters into three of eight tetrad differences which exceed five times their probable error. On the other hand, if Spearman's test for specific correlation be applied as between the Cube Construction test and the Dearborn Formboard test, no satisfactory proof of the existence of specific correlation between these two tests is obtained. What relation there is must be attributed solely to the "g" factor. We may conclude, then, that this test measures a special ability, but, on the present data, it is not possible to say whether this ability also enters into success in the Cube Construction and in the Form Relations tests. Much discussion has already arisen as to whether tests which require ability in apprehending spatial relations involve any factor common to them all, over and above that due to general intelligence; in other words, whether there is sufficient resemblance between the results of the separate tests to suggest the presence of a " group " factor of spatial ability. Other investigators have suggested that such an ability does exist and there are indications of it here. Hence the test might be particularly valuable in vocational problems, since spatial relations are important in many industrial activities.

The results for girls are more striking as regards this point. The raw correlation between this test and the Form Relations test is, in one group, as high as ·96. The correlation with "g" is also higher than it is for boys. In neither case, however, is it low enough to suggest that the test is mainly useful as a measure of some special ability. Hence we may reasonably conclude that this test is useful both to predict success in activities involving spatial relations, and as a suitable component of a scale of tests designed to measure " g."

(vi) *Cube Construction Test.*

The above remarks concerning the Dearborn Formboard Test apply also to this test. It enters into two of the eight tetrad differences which exceed five times their probable error. The correlation with "g" is, however, higher than in the case of the Dearborn Formboard test. It may be concluded that, like the Formboard, this test measures an ability to deal with relations of form, while it also serves as a rough measure of "g." In the case of girls the correlation with "g" is slightly lower than for boys; but how far the specific factors influence the results for girls it is difficult to say.

2.—THE VALUE OF THESE TESTS AS MEASURES OF "g."

If the Spearman criterion is a valid one, there is considerable justification for the belief that all the performance tests under consideration in this report are partial measures of "g." The results given in previous tables are summarised in Table XL.

TABLE XL.—*Average correlation of each test with other measures of "Intelligence."*

Test	"g"	Intelligence Group Test	Stanford-Binet Test.	Composite of Group Test and Stanford-Binet Test.[1]
Substitution	·60	·45	·44	·52
Cube Construction . .	·57	·35	·32	·39
Porteus Mazes . . .	·53	·30	·47	·51
Dearborn Formboard . .	·53	·33	·33	·39
Picture Completion . .	·51	·31	·38	·42
Cube Imitation . .	·48	·39	·43	·53

It will be seen that the correlations of the six performance tests with "g" are higher than any we obtained between these performance tests and either the Stanford-Binet test or the Intelligence group test; but they are lower than those usually found between the components of such group tests (analogies, opposites, etc.) and "g."[2] Hence, although the performance tests measure "g" (whether this is intelligence as generally understood or not), they do not measure it as successfully as the more verbal type of test. In most of the performance tests the specific ability required for solution may be just as important as "g" in determining the result. Sex differences, however, seem to influence the actual proportion of "g" entering into each test. This may be compared with Burt's results for the Binet intelligence tests; he found that, although boys and girls are equal as regards mental age, sex differences occur in the mean scores for the component tests of the scale.[3]

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[1] Composite obtained by expressing scores in terms of standard deviations.

[2] Spearman, op. cit.

[3] Burt. op. cit.

The relation between a composite score in the six Performance tests and the scores in the Intelligence tests is expressed in the following correlation coefficients[1] :—

—	Correlation of Composite score with Stanford Binet Test.	Correlation of Composite score with Group Test.
Boys (38)	·44 ± ·088	·45 ± ·087
Girls (43)	·94 ± ·012	·61 ± ·064
Boys and Girls combined ..	·79 ± ·028	·60 ± ·048

These coefficients are not high enough to suggest that the composite score represents the "intelligence" of the individual apart from other factors. In other words the specific factors have not "cancelled one another out".

Bearing this in mind, it seems unwise to regard these six performance tests as exclusively tests of general intelligence. At the same time there is no justification for a belief in the existence of any factor other than "g" connecting *all* the performance tests, i.e., there is no large group factor of non-verbal ability established in these results.[2] This is not to say that there are no factors connecting some of them for there does appear to be some connection between tests of a like nature such as the spatial tests. Hence, to combine measures of a number of varied specific abilities, such as these performance tests are, into one common pool to be labelled "non-verbal ability" or "intelligence expressed in non-verbal terms" is likely to be an exceedingly unsafe procedure.[3]

In using performance tests of intelligence, therefore, it is advisable to consider each test separately, and by virtue of its correlation with "g" (or alternatively with well-standardised intelligence tests) to decide how far the result of the test supports other measures of intelligence.[4] But it is even more important to consider the extent to which success in the test is influenced by specific factors.

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[1] Spearman's formula for the correlation of sums was used to obtain these coefficients.

[2] It is perhaps suggestive that the "group test of intelligence" is responsible for most of the deviations from a pure hierarchy. In short, a general factor is more obvious when the verbal test is eliminated.

[3] Such a procedure is justifiable, on the two-factor theory, only when there is a sufficient number and variety of tests to ensure that the effects of the "s" factors will neutralise each other.

[4] It was for this reason that the use of a single composite score was avoided in the work of vocational guidance by considering the tests separately in terms of percentile ranks. This agrees with the results obtained by Wells who found a composite mental age unreliable owing to the wide scatter of the test scores for each individual.

It is perhaps advisable to mention again that we are here considering only performance tests which are suitable for use at the mental ages of 11 and upwards. The value of a scale of performance tests for the grading of children of low mental level (say from mental ages 5 to 10) is not in question. By using at these lower levels tests which cover a sufficiently wide range of processes, a composite score may be obtained, which, just as in the Binet scale, fairly represents the level of general ability. Even then, the validity of the result will depend greatly upon the number of tests and on their range of difficulty. That they are not so suitable as the ordinary linguistic intelligence tests at higher levels is perhaps due both to the gradual development of the importance of language in thought and to the increase in the part played by special abilities which at lower ages produce less effect.[1]

The correlation between the two linguistic tests—the group test and the Stanford-Binet—which is high for both groups, is interesting in the light of the conclusions of other investigators. If we examine the correlations of these two tests with "g" we find they are not so high as might be expected. This suggests that there must be some other factor common to both of them. It may be the influence of "schooling," or it may be facility in the use of language. No evidence, however, of the special influence of such language facility in ordinary intelligence tests was found by Davey.

3.—The Use of Performance Tests of Intelligence in Vocational Guidance.

The satisfactory use of performance tests of intelligence in vocational guidance depends upon the purposes they are intended to serve. As measures of intelligence at school leaving age it appears from the results obtained in our enquiry that they are of limited value. But the specific abilities which enter into success in them may have vocational significance. To determine the extent to which this is the case it is necessary to compare the success of a person in the tests with his efficiency in some occupation in which the same or similar abilities are needed.

Up to the present there have been very few occupational studies in which performance tests have been used. Simmat[2] used certain Cube Construction and Substitution tests in an experimental enquiry into the abilities required by apprentice carriage builders ; but apparently he found them not wholly suitable since he omitted them from his final series of tests intended for the purpose of selecting suitable apprentices. Similarly a Substitution test, after trial, found no place in his selection tests for painters. In both cases, however, significant positive correlations were obtained.

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[1] This general conclusion has been recently confirmed in a study (as yet unpublished) of the reliability of Performance Tests, carried out by Lichtenberger (M.) under the author's direction.

[2] Martin, Doig and Simmat: Psychological Tests applied to Apprentices. *Austral. J. of Psychol. and Philos., Vol. III,* 1925.

Link's[1] Cube Construction test (also used by Tagg[2]) in which 27 small painted cubes have to be built into one large one, differs from the Cube Construction test here described, but the processes involved are very similar. (We obtained a correlation of ·95 between these two tests for a group of 16 boys.)

More recently, in a report to the Industrial Fatigue Research Board, the National Institute of Industrial Psychology gave the results of the application of several performance tests to groups of apprentice fitters, carpenters, electricians and smiths. The correlations with trade proficiency (as estimated by the instructors) were as follows :—

TABLE XLI.—*Correlation of Performance Tests with Trade Proficiency.*

Test.	Trade.	Correlation with Trade Proficiency.	
		As estimated by instructors halfway through the course.	As indicated by "passing out" examination.
Porteus Maze	Fitters	**·44**	**·61**
Cube Construction	Fitters	**·42**	**·46**
Substitution	Electricians	**·38**	**·50**
Dearborn Formboard	Smiths	·62	**·56**
Picture Completion	Smiths	**·48**	·32

All the correlations printed thus **44** are significant (exceeding 3 times P E.).

These figures suggest that the abilities measured in the separate performance tests may have some connection with abilities in special trades. The results were not due merely to the operation of the "g" factor, since it was clearly demonstrated that there *was no relation between* trade proficiency and intelligence as measured by tests except in the case of the electricians who happened to have been selected by scholastic examination. But of course further studies are necessary before these tests can be depended upon as aids to the giving of specific vocational recommendations.

4.—CLASSIFICATION OF OCCUPATIONS.

The foregoing results also have a direct bearing on a classification of occupations which has found many supporters. Three groups have been distinguished, based on the nature of the work to be done, viz., work dealing chiefly with inanimate objects, work dealing chiefly with persons, and work dealing with such symbols as language or numbers. While classifications of this kind are usually intended to serve a "systematising" function, it is tempting to attach to them a psychological importance, and to regard individuals as differing in their ability to succeed in these separate groups of occupations.

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[1] Link, H. C.. "*Employment Psychology,*" 1920.

[2] Tagg, J.. *Nat. Inst. of Indust. Psychol.*, July, 1925.

So far as the results here reported go, they suggest that, in addition to "g," there is a bond of connection between two different linguistic tests, and perhaps also between tests involving spatial relationships. But whether either deserves the title of a "group" ability is doubtful. Linguistic ability, however, is clearly essential in certain kinds of work; perception of spatial relations is obviously connected with work with concrete material. Differences of this kind are readily observable in everyday life, and there is accordingly some justification for the above-mentioned classification which has been empirically adopted. But even if it is useful to make such distinctions, it should be borne in mind that there are probably no clear-cut types. Although "group" abilities may exist, they are not invariably manifested, probably owing to the influence of specific factors. Moreover, sex differences occur with regard to these specific abilities. So far as one can generalise at all, specific abilities appear to be somewhat more marked in boys at this age than in girls—a difference observed by other English investigators of mental differences between the sexes.[1] Conversely, in several of the tests here used, the influence of "g" appears to be greater in girls than in boys. Hence the evidence of ability in work which requires the perception of relations of form given by good scores in several spatial tests can only be looked upon as a rough guide. The measurement of one or other of a person's specific abilities does not, of course, enable the whole range of his capacities to be deduced, and, in any case, the influence of his general ability must be taken into account.

Nevertheless, we may conclude from the data provided in this report, that the threefold classification of occupations is probably more useful for boys than for girls. We may also suggest that the phrase "work requiring ability in spatial perception" carries a more precise meaning than "work dealing with inanimate objects (or things)." Nothing can be said here as regards the abilities required in "work dealing with people" since the tests under discussion provide no relevant data.

Of course what has been said so far on the existence of types of ability is based only on test scores and does not deal with the possibility of distinctions of "type" based on temperament. It may well be that such differences are not manifested in the test scores because in such a short space of time all, except perhaps very young children, can be keyed up to a maximum effort, however distasteful the task. Hence the importance of noting the behaviour of the subject during the testing. It is in the situations of daily work where effort must be continued year after year that the question of interest in the material worked with becomes vitally important. It is quite possible that a "practical type" exists, not necessarily in the sense that such persons have the ability to work best with concrete material, but in the sense that only by concrete material can they be stimulated by a sustained effort at or near the maximum.

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[1] cf. Burt and Moore: "The Mental Differences between the Sexes." (*J. Exp. Ped.* 1919). McFarlane. M. A Study of Practical Ability. (*Brit. J. Pyschol.* Monograph Supp., Vol. III, No. 8.).

If this be the case, how can such persons be identified? During the administration of the tests, individual variations in reaction to the test situation can be noted. Since such variations do not always affect the test scores, the existence of a "practical bent" cannot be demonstrated by any statistical analysis. But observation shows that some individuals exhibit interest and confidence in their approach to the test problem, while others appear bored and confused. No experimental data are at present available for determining the generality of such reactions in any one individual for all kinds of concrete material. Indirect evidence is provided by Freyd[1] in connection with differences between the "socially and mechanically inclined." He found that in interests and in character traits a group of life-insurance salesmen differed markedly from a group of engineers. Assuming that such interests exercise a permanent influence upon a person's response to the demands of life, there are good grounds for making a distinction between occupations according to differences in the material dealt with, and according to the kind of response required. From this point of view, performance tests have a considerable value in the work of Vocational Guidance.

V.—Summary.

In this report we have dealt only with six selected tests of the performance types, but we have aimed at presenting our data in such a way as to answer several important questions. The practical work of examining school-leaving children of approximately fourteen years of age brought to light numerous difficulties and inconsistencies which demanded explanation. We found that as affording a "composite" age-scale even the complete series of tests had its limitations and that the tests most suitable for children of fourteen could not be combined into any really satisfactory single "total score." Accordingly we endeavoured to determine the exact part played by general intelligence in securing success in the separate tests, and to obtain some information as to the relative importance of the specific abilities required, the measurement of which, it seemed to us, is quite as valuable for the purposes of vocational guidance as the determination of the more general abilities which are also involved.

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[1] Freyd, Max "The personalities of the socially and mechanically inclined." *Psychol. Monograph No. 151,* 1924.

The principal results of this inquiry may be summarised as follows :—

1. The norms expressed as mental ages for the separate performance tests which have been published in previous reports do not seem to be consistently applicable to the London elementary school children of school-leaving age who were examined in the present investigation. Separate norms for boys and girls are also desirable.

2. The use of mental age norms in the case of the performance tests here described leads to difficulties of interpretation. This seems to be due to the fact that the abilities measured by the tests do not develop uniformly from age to age as general intelligence appears to do. Consequently, using the mental age method of interpretation, a boy or girl may have a mental age of 16 years in one test and one of 10 years in another test. This is confusing when mental age is generally regarded as a *function of intelligence,* and when the tests are measures of abilities other than, as well as, intelligence.

3. Each of the performance tests reveals the play of one or more special abilities, and, according to their correlations with the general factor " g " or with linguistic tests of intelligence, these special abilities play an important part in determining success in the tests. At the same time success in each test also depends upon the factor of general intelligence ; and, to the extent to which it does so, it may be regarded as a measure of intelligence. But the relative parts played by intelligence and by the special abilities required need careful consideration for each separate test. It is probable that the special abilities tend to show themselves more definitely about the age of puberty than previously.

4. For these reasons a composite mental age norm (median mental age), derived from the results of a number of performance tests, is not recommended at the age of 13 or 14. Such a combined score, however, is probably more reliable for younger children, because, for them, success in the tests depends mainly on general intelligence, the specific factors involved at later stages having not yet made their appearance. It may also be more reliable for girls since, if the differences disclosed in these results are to be relied upon, they seem to use general intelligence more than special abilities. The correlation coefficient of the composite of six tests with the Binet test is ·94 for girls as against ·44 for boys. (cf. p. 61.)

5. If, however, the tests be chosen according to the size of their correlations with intelligence (or " g "), each may be used as a valuable supplement to a linguistic intelligence test, with the added advantage that temperamental difficulties or a language bias may thereby be detected.

6. The special abilities entering into the six performance tests under consideration appear to be unrelated except in the case of those in which spatial elements enter. Although the Spearman

criterion is very largely satisfied, there is some support for the view that an ability to deal with relations of shape and size influences success in the tests of Cube Construction, Mechanical Ability, Immediate Visual Memory, Formboard (Dearborn), as well as in the group test of Form Relations. In other words, abilities required in the Cube Construction test and in the Formboard tests (of the six performance tests studied) are related by a group factor for spatial perception as well as by the general factor "g."

7. Of the six tests under review the Cube Imitation Test is the only one which requires careful examination before it is included in a series of tests supplementary to the Stanford-Binet or Group Intelligence Test.

8. As to the existence of " group " factors over a wider range—such as the so-called " non-verbal " or " practical " ability—there is, however, no conclusive evidence. That there is a factor common to all the performance tests is certain ; but whether it consists only of the " general factor " common to all mental tests or of this factor in combination with some group factor cannot be decided on the evidence of these results. Although there is apparently a specific factor in the intelligence group test which is not shared by the six performance tests (and therefore is suggestive of a " verbal ability " factor), it does not necessarily follow that the performance tests share a " non-verbal " factor. (pp. 60–62.)

9. The abilities required for success in some of these tests (Cube Construction, Formboard, Mazes, Substitution) are related to proficiency shown during apprenticeship to certain manual trades. (p. 63.)

10. Significant reactions are aroused by the situations created while the performance tests are being performed ; systematic observations of these reactions are valuable in determining whether a suitable adjustment to particular kinds of work is likely to be developed.

The authors desire to express their indebtedness to Dr. C. S. Myers, F.R.S., Director of the National Institute of Industrial Psychology, for the invaluable guidance received from him throughout the preparation of this report, to the members of the Committee on Industrial Psychology generally for many helpful comments, and to Miss E. M. Newbold, of the Statistical Branch of the Medical Research Council, for suggestions concerning the statistical treatment of the results.

BIBLIOGRAPHY.

LEAMING, R. E. (1922): "Test and Norms for Vocational Guidance at the Fifteen-year-old Performance Level."—*Psychol Clinic.*, **14**.

HOLLINGWORTH, R. L. (1923): "*Special Talents and Defects.*"—New York, Macmillan Co.

DEARBORN, W. F., SHAW, G. A. and LINCOLN, E. A. (1923): "*A Series of Formboard Performance Tests of Intelligence.*"—Harvard Monographs in Education.

PORTEUS, S. D. (1922): "*Studies in Mental Deviations.*"—Vineland Training School. New Jersey.

WOODWORTH and WELLS: Association Tests.—*Psychol. Monograph*, **18**, 5, pp. 53–55.

PINTNER, R. (1926): "An Empirical View of Intelligence."—*J. Educ. Psychol.* Vol. XVII. No. 9.

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Ruch and Koerlt (1923): "Power v. Speed in Army Alpha." —*J Educ. Psychol.* Vol XIV. No. 4.

Gates, A. I. (1923): "The unreliability of the M.A. and I.Q."—*J. Applied Psychol.* Vol. VII.

Drever, J. and Collins, M. (1928): *Performance Tests of Intelligence.*—Edinburgh, Oliver and Boyd

Wells, F. L. (1927): *Mental Tests in Clinical Practice.*—New York, World Book Coy.

APPENDIX.

Tables showing frequencies of occurrence of Tetrad differences of different magnitudes.

Distributions of Tetrad Differences (taking each difference once).

Table A.

Tetrad Differences of Figure 16.

Difference.	*Frequency.*
+·1375 to ·1126	6
·1125 to ·0876	17
0875 to ·0625	31
·0625 to ·0375	36
·0375 to ·0125	71
·0125 to ·0124	91
—·0125 to ·0374	57
·0375 to ·0624	37
·0625 to ·0874	18
·0875 to ·1124	4
·1125 to ·1374	5
·1375 to 1624	5

Table B.

Tetrad Differences of Figure 17

Difference	*Frequency*
+·139 to ·120	1
·119 to ·110	2
·099 to ·080	12
·079 to ·060	14
·059 to ·040	28
·039 to ·020	41
·019 to ·000	58
—·001 to ·020	70
·021 to ·040	60
·041 to ·060	49
·061 to ·080	17
·081 to ·100	19
·101 to ·120	5
·121 to ·140	2

Table C

Tetrad Differences of Figure 18.

Difference.	*Frequency.*
+·60 to ·57	1
·56 to ·53	0
·52 to ·49	1
·48 to ·45	3
·44 to ·41	4
·40 to ·37	1
·36 to 33	1
·32 to ·29	4
28 to ·25	8
·24 to ·21	18
·20 to ·17	30
·16 to ·13	41
·12 to ·09	57
·08 to ·05	77
·04 to ·01	76
—·00 to ·03	89
·04 to ·07	76
·08 to ·11	57
·12 to ·15	39
·16 to ·19	18
·20 to ·23	6
·24 to 27	5
·28 to ·31	9
·32 to ·35	2
·36 to ·39	3
·40 to ·43	1
·44 to ·47	0
·48 to ·51	2
— 52 to ·55	0
·56 to ·59	1

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Gaw, F. (1923): The Use of Performance Tests and Mechanical Tests in Vocational Guidance.—*J. Nat. Inst. Ind. Psych.*, **1,** 8.

Greenwood, M., and Newbold, E. M. (1923): On the Estimation of Metabolism from Determination of Carbon Dioxide Production and on the Estimation of External Work from the Respiratory Metabolism.—*J. Hyg.*, **21,** 4.

Hambly, W. D., and McSwiney, B. A. (1922): The U-tube Manometer Test with relation to Muscular Exercise.—*Proc. Physiol. Soc.*, Oct. 21, 1922.

Hambly, W. D., Pembrey, M. S., and Warner, E. C. (1925): The Physical Fitness of Men assessed by various Methods.—*Guy's Hosp. Rep.*, Oct., 1925.

Hewitt, E. M., and Bedale, E. M. (1923): A Study of the Comparative Physiological Costs of Different Methods of Weight Carrying by Women.—*Ann. Rep. of the Chief Inspector of Factories for* 1922.

Hill, A. V. (1927): *Muscular Movement in Man.* New York.

Hill, A. V. (1927): *Living Machinery.* London.

Hill, A. V., Long, C. N. H., and Lupton, H. (1924): Muscular Exercise, Lactic Acid and the Supply and Utilisation of Oxygen.—*Proc. Roy. Soc.*, B **96,** 438; **97,** 84; **97,** 155.

Hill, A. V., and Lupton, H. (1923): Muscular Exercise, Lactic Acid, and the Supply and Utilisation of Oxygen.—*Quart. J. Med.*, **16,** 62.

Hill, L., Vernon, H. M., and Hargood-Ash, D. (1922). The Kata-Thermometer as a Measure of Ventilation.—*Proc. Roy. Soc.*, B **93,** 198.

James, H. E. O., and Thouless, R. H. (1926). A Note on the Effect of Polarisation in Psycho-Galvanic Experiments.—*Brit. J. Psych.*, **17,** 1.

Lupton, H. (1922). Relation between External Work and Time Occupied in a Single Muscular Contraction.—*J. Physiol.*, **57,** 1 & 2.

Lupton, H. (1923). Exercise and Oxygen.—*Med. School Gaz.*, **2,** 3.

Lupton, H. (1923): Analysis of the Effects of Speed on the Mechanical Efficiency of Human Muscular Movement.—*J. Physiol.*, **57,** 6.

Muscio, B. (1920). Fluctuations in Mental Efficiency.—*Brit. J. Psych.*, **10,** 4.

Muscio, B. (1921): Is a Fatigue Test Possible?—*Brit. J. Psych.*, **12,** 1.

Muscio, B. (1921): Feeling Tone in Industry.—*Brit. J. Psych.*, **12,** 2.

Muscio, B. (1922): Motor Capacity with Special Reference to Vocational Guidance.—*Brit. J. Psych.*, **13,** 2.

Muscio, B., and Sowton, S. M. (1923). Vocational Tests and Typewriting.—*Brit. J. Psych.*, **13,** 4.

Newbold, E. M. (1923). Note on Dr. Burnside's Paper on Errors of Observation.—*Biometrika*, **15,** 3 & 4.

Pear, T. H. (1927). Repetitive Work.—*Dictionary of Industrial Administration.*

Pear, T. H. (1927). Work, Temperament and Fatigue.—*Rep. Internal Ass. for Study of Relations and Conditions in Industry.* (Baveno), 1927.

Pear, T. H. (1927). Recent Studies of Skilled Performance with reference to Transfer of Training.—*Nature*, 18th Jan.

Pembrey, M. S., and Others (1922): Tests for Physical Fitness.—Part I.—*Guy's Hospital Reports*, Oct., 1921. Part II.—*Ibid.*, Oct., 1922.

Rusher, E. A. (1922). The Statistics of Industrial Morbidity in Great Britain.—*J. Roy. Stat. Soc.*, **85,** 1.

Sargent, R. M. (1926). The Relation between Oxygen Requirement and Speed in Running.—*Proc. Roy. Soc. B.*, Vol. **100,** 1926.

Smith, May (1923): Practical Problems of Industrial Life.—*Ind. Welfare*, **5,** 58.

Smith, May (1923): The Laundry Trade.—*Laundry Record*, **33,** 388.

Smith, May (1926): Industrial Psychology.—*Article in Enclyclopædia Britannica* (*XIIth Edition*).

Sturt, M. (1922): A Comparison of Speed with Accuracy in the Learning Process.—*Brit. J. Psych.*, **12,** 3.

Vernon, H. M. (1921). The Influence of Atmospheric Conditions on Industrial Efficiency.—*J. State Med.*, **29,** 353.

Vernon, H. M. (1921): The Influence of Fatigue on Health and Longevity.—*J. Ind. Hyg.*, **3,** 3.

Vernon, H. M. (1922): Recent Investigations on Atmospheric Conditions in Industry.—*J. Ind. Hyg.*, **4,** 8.

Vernon, H. M. (1923): A Note on the Causes of Output Limitation.—*J. Nat. Inst. Ind. Psych.*, **1,** 5.

Vernon, H. M. (1923): Atmospheric Conditions in Potters' Shops and the Efficiency of Various Types of Drying Stoves.—*Trans. Ceramic Soc.*, 22, p. 70.

Vernon, H. M (1923) . The Causation of Industrial Accidents.—*J Ind. Hyg.*, **5,** 1.

Vernon, H. M , and Bedford, T (1924) · The Influence of Short Time on Speed of Production —*J Nat Inst Ind. Psych* , **2,** 155

Vernon, H M (1925) · Can Laboratory Experiments on Output throw Light on Problems of Industrial Fatigue ?—*Brit J. Psych,* **15,** 4

Vernon, H M (1925) . The Kata-Thermometer as an Indicator of Radiant Heat —*J Nat Inst Ind Psych* , **2,** 198

Vernon, H M (1925) . The Work of the Tin-Plate Doubler.—*J. Nat. Inst Ind Psych* , **2,** 373

Vernon, H M (1926) . Is Effective Temperature or Cooling Power the Better Index of Comfort ?—*J Ind Hyg.*, **8,** 392

Vernon, H M (1927) The Elimination of Fatigue caused by Extremes of Temperature, Humidity and Dust —*Rep Internat Ass for Study of Human Relations and Conditions in Industry* (Baveno), 1927.

Vernon, H M (1927) · Ventilation in relation to Health.—*J State Med.* **34,** 683

Vernon, H M (1927) The Wet Kata-thermometer as an Index of the Suitability of Atmospheric Conditions for Heavy Work —*J. Indust Hyg* , **9,** 287

Vernon, H M , and Others (1926) Methods of Investigating Ventilation and its Effects.—*Med. Res Council Spec Rep Series No.* 100.

Vernon, H M , and Bedford, T (1927) The Ventilation and Heating of Factories —*J Indust Hyg* , **9,** 51

Vernon, H M., and Vernon, M D (1927) · The Physical and Physiological Effects of Radiant Heating by the Panel System —*Proc. Physiol Soc J Physiol* , **64,** 1

Vernon, M D (1926) On Certain Effects of Long Spells of Repetitive Work.—*Brit J Psych.*, **16,** 3

Warner, E. C , and Hambly, W D (1925) An Investigation into the Physiological Basis of the U-tube Manometer Test.—*Guy's Hosp. Rep* , July, 1925

Weston, H. C. (1927) The Relation between Illumination and Efficiency in Fine Processes, with special reference to the Lighting of Printing Works —*Illum Engineer,* **20,** 221.

Weston, H C. (1927) : Light and Vision in Industry —*Rep. Internat. Ass. for Study of Human Relations and Conditions in Industry* (Baveno) 1927.

Wilson, D. R. (1921) : Some Effects of Environment on Efficiency and Safety.—*J. Roy. San. Inst* , **42,** 3.

Wilson, D. R (1921) · The Work of the Industrial Fatigue Research Board, and its Applications to Industry.—*J. Roy. Soc Arts.*, **70,** 3660.

Wilson, D. R. (1923) . On Some Recent Contributions to the Study of Industrial Fatigue.—*J Roy Stat. Soc.*, **86,** 4.

Wilson, D. R (1923) : International Co-operation in the Study of Industrial Psychology and Physiology.—*International Labour Office, Studies and Reports, Sec F* , *No* 9.

Wilson, D. R. (1924) : Some Observations on Industrial Lighting.—*J. Ind. Hyg.*, **5,** 10.

Wilson, D R (1924) · Man in Relation to Production.—*First World-Power Conference,* **412.**

Wyatt, S. (1925) : The Effect of Atmospheric Conditions on Health and Efficiency (with special reference to the Cotton Industry) —*J. Ind. Hyg.*, **7,** 7.

Wyatt, S. (1927) : An Experimental Study of a Repetitive Process.—*Brit. J. Psych.*, **17,** 3.

Wyatt, S. (1927) : Machine Speeds and Output.—*J. Nat Inst. Indust. Psych.*, **3,** 8.

Wyatt, S., and Weston, H. C. (1920) : A Fatigue Test under Industrial Conditions.—*Brit J Psych.*, **10,** 4

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INDUSTRIAL
FATIGUE RESEARCH BOARD.

REPORT No. 54.

An Investigation into the Sickness Experience of Printers

(with special reference to the incidence of Tuberculosis).

By A. Bradford Hill, Ph.D.

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INTRODUCTORY SUMMARY.

It has been known for many years that while the death-rates of printers from *all causes of death excluding tuberculosis* are, at nearly all ages, definitely lower, their death-rates from *tuberculosis* are at all ages definitely higher, and often very considerably higher, than the corresponding rates for all occupied males. In other words, persons employed in the printing industry in England and Wales die from tuberculosis at a higher rate than would be expected. This is clearly seen in Table A, in which the latest figures (1921–23) suggest that the discrepancy still persists to some extent. This circumstance has led to a great deal of attention being paid, in several countries, to the problem of the reasons for this difference, and various explanations have been suggested. For example, it has been stated that the printer's liability to tuberculosis is due to his contact with lead ; or, again, that he works in close, cramped quarters with insufficient ventilation and is therefore easily exposed to infection ; or, thirdly, that the industry being one which needs no great physical exertion may attract persons of poor physique who are already phthisically inclined None of these explanations, however, are based upon adequate proofs and the question still remains unanswered.

TABLE A.—*The Mortality Rate of Printers for* 1900–02, 1910–12, 1921–23, *expressed as a percentage of the mortality rate for all males.**

Period.	Cause.	Age.							
		15–	20–	25–	35–	45–	55–	65–	75 and up.
1900–02	All causes, less tuberculosis ..	105	90	70	71	91	92	92	
	Tuberculosis ..	175	214	166	170	135	144	115	
1910–12	All causes, less tuberculosis ..	90	85	71	78	89	90	94	87
	Tuberculosis ..	129	186	148	142	142	128	158	52
1921–23	All causes, less tuberculosis ..	109	91	100	85	92	102	98	84
	Tuberculosis ..	206	124	122	120	119	147	171	103

* This table reads as follows .—In 1900–02 the death-rate of printers from all causes of death excluding tuberculosis was, at ages 15–20, 105 per cent. of the corresponding rate for all males during these years ; at ages 20–25 it was 90 per cent , and at ages 25–35 it was 70 per cent. and so on. The printers' death-rate from tuberculosis was in these years 175 per cent. of the death-rate from tuberculosis amongst all males at ages 15–20, 214 per cent., at ages 20–25, 166 per cent., at ages 25–35 and so on. It must not be thought that these percentages show the trend of the " all causes " or " tuberculosis " death-rates over this quarter of a century. The increase in the percentage at ages 15–20 between 1900 and 1923 does not mean that the death-rate has risen, but that the fall in the printers' rate has been slower than the fall in the rate for all males.

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In 1925, the Joint Industrial Council for the Printing and Allied Trades and the Newspaper Proprietors' Association of London, approached the Industrial Fatigue Research Board with a request that they would arrange for some inquiry into the problem, at the same time offering their fullest collaboration together with a financial contribution towards the necessary expenditure. Since the printing industry in Great Britain employs, roughly, a quarter of a million persons distributed throughout the whole country, the Board had no hesitation in deciding that further investigation was fully justified, and gladly accepted the proposal.

The question was then referred for consideration to a special Committee composed of representatives of the Board, of the Home Office, of the Joint Industrial Council and the Newspaper Proprietors' Association of London, and of the Statistical Committee of the Medical Research Council, which recommended that an investigation should be made of the incidence of sickness, both from tuberculosis and from all other causes, amongst the different occupational groups within the industry. Such an investigation, it was realised, could not explain the relatively high tuberculosis rates amongst printers, but it might show whether the peculiarity was derived from any particular occupation and thus pave the way for further inquiry.

The results of this investigation of the sickness amongst printers, which was entrusted to Dr. A. B. Hill, are given in the present report. A report of this kind is necessarily made up of large numbers of statistical tables and of a discussion both of the figures contained in them and of the somewhat intricate analysis by which they have been reached. It is inevitably lengthy and not easy to follow. On the other hand, all these data must be presented in full, not only as proof of the conclusions reached and for the critical consideration of any persons who are closely interested, but also because many of these figures may have an interest to the scientific or social worker quite apart from their bearing on the printing industry. It has been thought wise, therefore, in view of the technical and elaborate character of the report, to give in this preface (in addition to the summary at the end of the report) a simple and short outline of the method of inquiry adopted and the results reached by it.

The data needed for assessing the amount of sickness suffered in each occupational group were obtained from the Approved Societies administering benefits under the National Health Insurance Acts. Those Societies were used which are attached to the Trade Unions of the printing industry, or are open (on the whole) only to members of the printing industry. There were nine of these and they supplied the necessary data for about 36,000 males, and, with the addition of a more "general" society, of about 3,000 females.* The amount and causes of the sickness suffered by these persons during the years 1921–25 (inclusive) were examined, and related to the occupation which they followed. The occupational groups used are shown in Table B.

TABLE B.—*The Occupational Groups of Printers examined.*

Occupational Group	Total Number of persons coming under observation during 1921–25.
Compositors	14,507
Machinemen†	6,901
Stereotypers and electrotypers	1,563
Bookbinders and rulers	3,836
Warehousemen and cutters	2,316
Typefoundry workers and Monotype casters	105
Lithographic printers	3,741
All printers	32,969
Journalists	960
Lithographic artists	2,119

† Including Lithographic Printers' Assistants.

The figures for the last two groups, however, were not considered satisfactory (as these workers are not manual workers according to the definition of the National Health Insurance Acts) and they have not been used.

The amount of sickness suffered by the other groups taken as a whole was first compared with the amount of sickness suffered by a general sample of the whole insured population in the years 1921–23. This is summarised in Table C, which shows that printers experience appreciably less sickness than all insured males.

---

* The Approved Societies by whom the necessary facilities were granted, to the officials of which the Board are greatly indebted for the help so readily given, were the following:—

A.S. 224. National Society of Electrotypers and Stereotypers.
A.S. 267. National Union of Journalists.
A.S 289. Amalgamated Society of Lithographic Artists, Designers, Engravers and Process Workers
A.S. 292. National Society of Operative Printers and Assistants.
A.S. 301. Typographical Association.
A.S. 330. National Union of Printing, Bookbinding, Machine Ruling and Paper Workers.
A.S. 346. Amalgamated Society of Lithographic Printers and Auxiliaries thereto.
A.S. 1096. Friendly Benefit Society of Managers of Printing Machines.
A.S. 1328. Separate Section of London Society of Compositors.

The "General" society for women only was —

A.S. 1231. Manchester, Salford and District Women's Trade Society

TABLE C.—*Sickness* (*first* 26 *weeks*) *and Disablement* (*incapacity after first* 26 *weeks*) *amongst all Printers compared with that experienced by the general sample of the insured population for the years* 1921–23.

	Sickness (first 26 weeks)			Disablement (incapacity after first 26 weeks).		
Age Group.	Rate in days per person-year.		Printers' rate as per-centage of general sample rate	Rate in days per person-year		Printers' rate as per-centage of general sample rate
	Printers.	General sample		Printers.	General sample	
16–19	4·23	4·41	96	·85	·63	135
20–24	3·56	4·69	76	1·27	1·19	107
25–29	3·37	4·69	72	1·74	1·75	99
30–34	3·18	4·97	64	2·59	2·10	123
35–39	3·72	5·25	71	2 14	2·73	78
40–44	4·23	5·60	76	3·03	3·36	90
45–49	4·81	6·30	76	3·58	4·27	84
50–54	5·56	7·70	72	4·27	5·53	77
55–59	6·76	9·73	69	7·27	9·87	74
60–64	9·93	12·95	77	15·99	17·78	90

In short-period illness (first 26 weeks of incapacity) they have roughly only three-quarters of the sickness of all insured men, except in the first years of insurance, at ages 16–19, when their rate is very nearly as high as that for all insured men. In long-period illness (illness after the first 26 weeks of incapacity) they are again less well off in early employed life but after age 35 they have only about four-fifths of such illness suffered by all insured men.

When the occupational groups were compared with one another, certain differences, as shown in Table D, became evident Compositors, it was found, have a larger amount of illness than the other groups in the first few years of insured employment and this excess is maintained for many causes of sickness, including tuberculosis. Yet, on the other hand, in later employed life, and up to age 60, they have distinctly less illness from most causes, than others in the printing trade. Their only rivals are the bookbinders and rulers who have still less sickness of short duration—although the claims they do make were found to be of greater length—but suffer more considerably from illnesses of long duration. Machine printers and warehousemen and cutters in the first years of insured employment do not have the high rates found for the compositors, but they have, on the whole, a distinctly larger amount of illness in later employed life.

TABLE D.—*Sickness (first 26 weeks) and Disablement (after first 26 weeks of incapacity) in each occupational group for the years* 1921–25. *Number of days Sickness and Disablement suffered per person-year.*

Age Groups.	Sickness						Disablement					
	Compositors.	Machine Printers.	Stereotypers and Electrotypers.	Bookbinders and ·Rulers	Warehousemen and Cutters.	Lithographic Printers.	Compositors	Machine Printers	Stereotypers and Electrotypers.	Bookbinders and Rulers	Warehousemen and Cutters	Lithographic Printers.
16–19 ..	5·23	4·27	3·87	4·43	3·71	4·13	1·47	·67	—	·55	·15	·38
20–24 ..	3·56	3·56	3·27	3·55	2·53	4·70	1·04	1·53	—	1·71	·98	3·62
25–29 ..	3·32	4·04	3·52	2·87	4·88	3·12	1·61	1·81	·40	2·98	4·09	1·13
30–34 ..	3·05	4·63	3·72	2·78	4·08	3·86	2·51	2·38	1·12	2·18	1·90	2·62
35–39 ..	3·34	4·32	3·44	3·56	6·65	3·84	2·03	2·57	1·63	1·45	5·67	1·29
40–44 .	3·44	5·97	4·83	3·47	5·35	4·49	2·30	2·76	2·41	6·66	4·78	2·04
45–49 ..	4·66	6·56	4·70	4·01	6·09	4·77	3·44	3·93	3·77	5·85	4·35	3·41
50–54 ..	5·21	7·50	7·08	5·44	7·06	6·66	3·16	6·75	4·71	5·08	10·05	4·57
55–59 ..	6·81	9·71	8·60	6·87	7·63	6·64	7·76	6·58	6·12	6·78	2·31	10·48
60–64 ..	9·65	11·12	9·30	10·33	12·89	10·42	18·28	12·62	15·73	23·93	9·01	19·41
65–69 ..	16·08	18·61	15·52	13·64	15·30	16·53	47·21	36·08	29·03	25·14	14·32	31·15
All ages (Standardized).	4·86	6·42	5·39	4·68	6·25	5·36	5·12	4·99	4·08	5·82	4·96	5·07

These higher rates in later life are traceable to a general inferiority at the older ages, for these workers suffer then to a greater extent from most causes of illness, including, for the machine printers, tuberculosis which is distinctly high for such workers of ages 40–59. Lithographic machine printers do not show this high tuberculosis rate and have, on the whole, a smaller amount of illness than the machine printers. Stereotypers and electrotypers make more claims than the compositors, but they are shorter claims, and they do not show any excess of tuberculosis. These workers—the stereotypers and electrotypers—and also the bookbinders and rulers, the warehousemen and cutters and the lithographic machine printers all form, in this inquiry, somewhat small groups. For this reason the sickness rates found for them are not absolutely reliable and it is not safe to draw very definite conclusions from them On the other hand the groups of compositors and machine printers are adequate to enable the very distinct differences observed between them to be taken as true differences. Table E shows the higher rates from tuberculosis found amongst compositors in early working life as opposed to the higher rates amongst machine printers in later working life.

TABLE E.—*The Incidence of Tuberculosis amongst Compositors and Machine Printers.*

Age Group	Compositors.		Machine Printers.	
	No. of cases.	No of cases per 100 person-years.	No of cases.	No. of cases per 100 person-years.
16–19	18	·46	5	·25
20–29	33	·42	9	·23
30–39	40	·30	33	·41
40–49	47	·32	48	·56
50–59	32	·24	29	·54
60–69	12	·20	1	·06

The high rate of sickness found amongst compositors in the first few years of insured employment, derived from nearly all causes of sickness, may be due, it is thought, to either or both of two factors, (1) the recruitment by the occupation of persons of poor physique; (2) unfavourable working conditions. It is suggested that the point should be further explored by a medical examination of apprentices at entry and during the apprenticeship period.

It is more difficult to offer an explanation of the higher sickness rates and the high tuberculosis rate amongst machine printers at older ages. If their amount of sickness be compared with that suffered by the general insured population in 1921–23 they are found to have less than these other workers. In other words their amount of sickness is high in comparison with skilled workers of their own class, but it is not high in comparison with the general insured population composed of workers of all types, skilled and unskilled. It is suggested that the differences found between the letterpress machine printers and the lithographic machine printers should be further examined, or different printing offices could profitably be compared.

An attempt to compare general printing offices with newspaper printing offices led, in this inquiry, to no useful results, for the figures provided could not enable all the various factors involved to be taken into account. Similarly the number of women involved in this inquiry was too small to allow any reliable result to be reached.

March, 1929.

AN INVESTIGATION INTO THE SICKNESS EXPERIENCE OF PRINTERS

(With Special Reference to the Incidence of Tuberculosis.)

By A. Bradford Hill, Ph.D.

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INTRODUCTION.

A study of the occupational mortality returns of the Registrar-General for England and Wales reveals the fact that printers, although they compare favourably in their general death-rate with all occupied and retired males, suffer unduly from tuberculosis. The comparison is set out in Table I where the death-rates at ages are given for all causes *less* respiratory tuberculosis and for respiratory tuberculosis alone for occupied and retired printers and all occupied and retired males for the years 1900–02, 1910–12 and 1921–23. In addition, the printers' rate is shown in each case as a percentage of the rate for all males.*

It will be observed that the printers' rate from all causes of death less tuberculosis is in nearly every case appreciably less than the same rate for all males occupied and retired. In most age groups it lies between about three-quarters and nine-tenths of the rates for all males, the only distinct exceptions being in the first age group, in which in 1900–02 the printers' rate exceeds the rate for all males by 5 per cent. and in 1921–23 by 9 per cent. With respiratory tuberculosis, on the other hand, the printers are consistently in an unfavourable position, their death-rate from this cause exceeding that for all males throughout life, often by a very considerable amount. Their adverse position with regard to this disease is not nearly so distinct in 1921–23 (except at ages 15–19), but it is still definitely in evidence. If printers, instead of being compared with the whole male population, are compared with the social class to which they belong, the discrepancy is still very nearly as large. In Table IA the mortality of printers from all causes *less* respiratory tuberculosis and from respiratory tuberculosis alone is compared with similar mortality rates for *skilled workers* (the Registrar-General's Social Class III in his occupational mortality report, 1921–23), i.e. excluding the upper and middle classes and agricultural workers amongst others. The printers compare with these workers in tuberculosis mortality nearly as unfavourably as they do with all males. This abnormal incidence of tuberculosis amongst a class otherwise the superior of the general employed population has led in many countries to a considerable amount of attention being paid to the printing industry with regard to the prevalence of phthisis. It has been quite widely concluded that this is one of the chief occupational diseases and various explanations of the phenomenon have been propounded. It has been asserted, for instance, that the printer is daily in close contact with lead and that this is the underlying cause.

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* It must be remembered in studying this table that the three periods are not strictly comparable one with another. Between 1900–02 and 1910–12, a slight change in grouping affecting printers took place, a change probably, however, not sufficient to vitiate comparison. Between 1910–12 and 1921–23, radical change took place, the grouping unit being altered from the industry to the occupation. Therefore, even for printers as a whole, the figures become incomparable with those for the earlier periods.

"Lead poisoning, when it occurs in printers, is of a slow, chronic, insidious form, not easily recognised because not typical. The chief injury done by lead is probably to be found not in the production of true plumbism, but in a lowering of the resistance to other diseases, especially to certain infections. In this way is explained the high death-rate [in the printing trade] from tuberculosis. Lead poisoning and tuberculosis go hand in hand in this trade, both being highest in the occupations with greatest exposure to lead and both falling as cleanliness and good ventilation increase."*

Alternatively, it has been held that the relatively excessive incidence is due to inadequate ventilation, cramped quarters and massive infections. In an American report more recent than the one previously quoted, it is stated that "the various [printing] trades have always ranked high among the special industries subject to tuberculosis, partly as a result of dust or carbon monoxide created by the processes, partly from poor ventilation with stagnant air or abnormal temperatures, and partly from lack of personal cleanliness or regular habits among the workers."† Considerable stress is laid in this report upon the use of illuminating gas and upon carbon monoxide poisoning.

Finally, it has been held that the cause may lie in the recruitment by the industry of persons of poor physique ; that, being an indoor industry demanding no great physical exertions, it "naturally attracts boys who are undersized, narrow-chested, deficient in muscular development, and therefore predisposed to tuberculous infection." Pannwitz, 30 years ago, from a study of the examination records made under the compulsory military service system in Germany concluded that there are an unusual number of weaklings in the industry.‡ In the United States 589 industrial policy holders working in the printing industry were found to be somewhat lower in height and weight than the general average for all other occupations.§ On the other hand a later American report, by Hoffman, concludes from the examination of 1,215 printing employées, that now there is no difference "sufficiently pronounced to be suggestive of men of a decidedly inferior physique seeking employment in the printing trades."‖ From the above brief résumé it will be gathered that the subject is a controversial one and that no satisfactory solution of its problems has yet been reached.¶

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* *Bulletin of the U.S. Bureau of Labor Statistics, No.* 209.—Washington. April, 1917, p 8.

† *Bulletin of the U S. Bureau of Labor Statistics, No.* 392 —Washington. September, 1925, pp. 7–12

‡ PANNWITZ : *Arbeiten aus dem Kaiserlichen Gesundheitsamt.* Berlin, 1896 Vol. XII (quoted in *Bulletin of the U.S Bureau of Labor Statistics,* No 209, pp 101–2).

§ *U.S. Bureau of Labor Statistics, No.* 209, pp. 101–2.

‖ *U.S Bureau of Labor Statistics, No.* 427 Washington, March, 1927.

¶ The Leipzig sickness experience contains a considerable amount of data relating to printers, but as this inquiry relates to the years 1887–1905, and probably to very different conditions of work from those existing to-day in this country, it was not considered necessary to present the figures here.

TABLE I.—*The Mortality of Printers from All Causes* less *Respiratory Tuberculosis and from Respiratory Tuberculosis compared with the like mortality of all occupied and retired males for* 1900–02, 1910–12 *and* 1921–23.* *Death-rates per* 1,000.†

		Age						
		15—	20—.	25—.	35—.	45—.	55—.	65 and up.
1900–02.								
Death-rate from all causes less tuberculosis.	Printers	2·00	2·61	2·92	5·65	14·10	30·31	96·47
	All males‡	1·91	2·91	4·15	7·99	15·54	32·96	104·72
Death-rate from tuberculosis..	Printers	·96	3·43	3·56	4·92	4·28	3·74	1·73
	All males . ..	·55	1·60	2·14	2·89	3·18	2·59	1·51
Printers' rate as percentage of rate for all males.	All causes, less tuberculosis.	105	90	70	71	91	92	92
	Tuberculosis	175	214	166	170	135	144	115

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* It must be remembered in studying this table that the three periods are not strictly comparable one with another. Between 1900–02 and 1910–12 a slight change in grouping affecting printers took place, a change probably, however, not sufficient to vitiate comparison. Between 1910–12 and 1921–23 radical changes took place, the grouping being altered from the industry to the occupation. Therefore, even for printers as a whole, the figures become incomparable with those for the earlier periods.

† Rates for printers calculated from data given in Registrar-General's Reports. In 1900–02 and 1910–12 the occupational groups used were printers, lithographers and bookbinders; in 1921–23 they were hand compositors, machine compositors, printing machine minders and assistants, and machine rulers, and bookbinders and pattern card makers.

‡ i.e. all occupied and retired males in each case.

TABLE I—*continued.*

		Age							
		15—.	20—.	25—	35—.	45—	55—	65—.	75 and up
1910–12.									
Death-rate from all causes less tuberculosis.	Printers	1·46	1·86	2·14	4·59	11·01	25·00	62·02	160·21
	All males	1·62	2·20	3·03	5·86	12·35	27·84	66·01	184·72
Death-rate from tuberculosis..	Printers	·75	2·46	2·48	2·96	3·26	2·82	2·39	33
	All males	·58	1·32	1·68	2·08	2·30	2·20	1·51	·64
Printers' rate as percentage of rate for all males.	All causes, less tuberculosis.	90	85	71	78	89	90	94	87
	Tuberculosis ..	129	186	148	142	142	128	158	52
		15—	20—	25—	35—	45—	55—.	65—.	70 and up
1921–23.									
Death-rate from all causes less tuberculosis.	Printers	1·95	1·96	2·67	4·07	9·09	24·60	47·75	113·78
	All males	1·79	2·15	2·66	4·79	9·90	24·22	48·77	135·21
Death-rate from tuberculosis..	Printers	1·42	1·68	1·62	1·92	1·97	2·20	1·95	66
	All males	·69	1·36	1·33	1·60	1·66	1·59	1·14	·64
Printers' rate as percentage of rate for all males.	All causes, less tuberculosis	109	91	100	85	92	102	98	84
	Tuberculosis ..	206	124	122	120	119	147	171	103

Table Ia.—*The Mortality of Printers from All Causes* **less** *Respiratory Tuberculosis and from Respiratory Tuberculosis compared with the like mortality of Skilled workers (R.-G's Social Class III) for* 1921–23. *Death-rates per* 1,000.

		Age.							
		15—.	20—.	25—.	35—.	45—.	55—.	65—.	70 and up
Death-rate from all causes less tuberculosis.	Printers	1·95	1·96	2·67	4·07	9·09	24 60	47·75	113·78
	Skilled workers ..	1·72	2·07	2·50	4·39	9·10	23·54	48·68	131·33
Death-rate from tuberculosis ..	Printers	1·42	1·68	1·62	1·92	1·97	2·20	1·95	·66
	Skilled workers ..	·71	1·40	1·29	1·51	1·60	1 55	1·20	·60
Printers' rate as percentage of rate for skilled workers.	All causes less tuberculosis.	113	95	107	93	100	105	98	87
	Tuberculosis	200	120	126	127	123	142	163	110

The Registrar-General's supplement on Occupational Mortality allows some analysis to be made of the risks amongst the various divisions of the industry. In the report for 1921–23 figures are given for four such sub-groups—hand compositors, machine compositors, printing machine minders and assistants and machine rulers, and bookbinders and pattern card makers. In Table II are set out the comparative mortality figures, as given by the Registrar-General, for these branches of the industry both for all causes and for respiratory tuberculosis. The comparative mortality figure is a standardised death-rate, a device for making comparable the death-rates of all employed persons when the populations concerned have differing age constitutions. Mortality being closely connected with age, allowance has to be made for this factor. (Obviously an occupation employing old persons will have a higher death-rate than a similar one employing young persons. Unless the age difference is taken into account the difference in mortality conveys nothing.) The table thus states that the mortality figure for the standard population of all males is 1,000; if the death-rates at ages actually found to prevail amongst hand compositors are applied to this standard population their mortality figure is found to be 1,007. These two figures are directly comparable, the differences in the age constitution of the population of compositors and the population of all males having been eliminated.*

These comparative mortality figures are taken direct from the Registrar-General's report.† The hand compositors and printing machine minders etc. have mortality figures for all causes sensibly equal to all males (and, therefore, for all causes *les* tuberculosis lower than all males since tuberculosis makes a relatively large contribution to all causes). Their tuberculosis mortality is considerably above that for all males, 1,289 and 1,247. Machine compositors have a distinct advantage for all causes—a mortality figure of 867 compared with the 1,000 for all males, and yet their tuberculosis rate rises to 1,320. Bookbinders show the least differentiation between all causes and tuberculosis and yet with them too there appears some excess of the latter.

TABLE II.—*Standardized Mortality of Males aged* 20–65 *years from All Causes and from Tuberculosis*, 1921–23.

	All Causes.	Respiratory Tuberculosis.
All occupied and retired civilian males . .	1,000	1,000
Hand compositors	1,007	1,289
Machine compositors	867	1,320
Printing machine minders and assistants, machine rulers	1,008	1,247
Bookbinders and pattern card makers . .	1,098	1,209

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* For definition, choice of standard population and method employed *vide* the Decennial Supplement, Registrar-General of England and Wales, 1921, Part II.

† *Ibid.* Table D pp cxxii–cxxv.

The Registrar-General is of opinion that these returns suggest no excessive risk under this heading of tuberculosis.* This is no doubt true if tuberculosis figures for printers be compared with such occupational classes as tin and copper miners with a comparative mortality figure for respiratory tuberculosis of 8,847, grinders with a figure of 7,878, or even boot and shoe clickers and cutters with a figure of 1,820. But the fact that the excess amongst printers is not great in such comparisons does not alter the fact that there is a distinct excess when the otherwise favourable position of the industry is remembered.

That is the crux of the problem. Why should printers have death-rates from all other causes definitely lower, as a whole, than the rates for all occupied and retired males, and yet die from tuberculosis at a rate that may not be excessively high, but undoubtedly is significantly higher than that for all males ? This question, it was considered, merited further investigation, especially in view of the size and importance of the industry, for nearly a quarter of a million persons are employed in it and their distribution is widespread over the whole of the country. In addition certain sections are acutely interested in the question and have already attempted some small-scale investigations.† At the request of the Joint Industrial Council for the Printing and Allied Trades and of the Newspaper Proprietors' Association of London, it was decided to proceed on a wider basis than could be adopted by any one section of the trade, to cover all sections of the industry, and it was agreed (as a preliminary step) to explore thoroughly the incidence of sickness, both from tuberculosis and from all causes, in each of the occupational branches of the industry. In this report are given the results of such investigation, which, naturally, can only hope to suggest the derivation of the excessive incidence of tuberculosis and not to explain its cause.

METHOD OF INVESTIGATION.

The data necessary for evaluating the various morbidity rates amongst printers are available in the records kept by the Approved Societies through which the National Health Insurance Acts are administered. Under these Acts records have to be kept by societies in approved form of all periods of incapacity suffered by their members. Printers may belong to the general Approved Societies, which are open, as a rule, to all types of workers. Large numbers of them, however, are naturally to be found in the societies whose membership is confined to their specific occupations, or which are attached to their Trade Unions. Two methods of securing the sickness data were thus possible :—

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* *Ibid.* p lxxxi.

† *Vide The Natsopa Journal,* June, 1925. Tuberculosis among Printers Assistants. *Interim Report of the Committee of Inquiry.*

(1) Taking the printing works as a unit, a "census" might be taken of the operatives, note being taken of the Approved Society to which each belonged. These Approved Societies could then be approached and the necessary records relative to these members be made. This method has the disadvantage of needing considerable organisation, for it demands the co-operation both of large numbers of firms and of Approved Societies. It has a greater disadvantage in that it can relate only to short period sickness (unless the inquiry is extended over a considerable number of years) for the totally and semi-totally incapacitated will be absent from work at any date selected for the "census." As tuberculosis is a sickness of long duration, a considerable amount of its incidence might be obscured in a study confined to short period sickness. This method has the advantage, on the other hand, of allowing sickness to be examined in relation to the environmental conditions of the workplace.

(2) The second method is to take the records direct from the Trade Approved Societies. This ignores the differentiation of workplaces, but still allows the occupational division to be made. (Actually the occupation in an Approved Society's records is the occupation notified at entry into insurance and the entry is rarely changed even though the occupation may change. As only very broad occupational groupings have been employed, it is improbable that any substantial error arises from this factor. The opinion of the representatives of the industry on the Committee directing the inquiry was that transference between the occupational groups is very small in volume.) The records since they relate, at any date, both to persons at work and to persons suffering incapacity, allow an examination of all sickness, both of short and long duration. The disadvantage is that the method only allows occupational risks to be studied, and not the environmental risks of varying types of workplaces.

It was decided to adopt the second method. The records were thus obtained from the nine Approved Societies attached to the trade, with the addition of one society of a more "general" type, which was in a position to supply data with regard to the women workers employed in the industry. These societies are as follows :—

A.S. 224	National Society of Electrotypers and Stereotypers.
A.S. 267	National Union of Journalists.
A.S. 289	Amalgamated Society of Lithographic Artists, Designers, Engravers and Process Workers.

A.S. 292	..	National Society of Operative Printers and Assistants.
A.S. 301	..	Typographical Association.
A.S. 330	..	National Union of Printing, Bookbinding, Machine Ruling and Papers Workers.
A.S. 346	..	Amalgamated Society of Lithographic Printers and Auxiliaries thereto.
A.S. 1096	..	Friendly Benefit Society of Managers of Printing Machines.
A.S. 1328	..	Separate Section of London Society of Compositors.

The " General " society for women only was :—

A.S. 1231	..	Manchester, Salford and District Women's Trade Society.

The years selected for examination were 1921–25 inclusive, i.e. a five years' record. For every member in each of these societies during this period (i.e. both for the whole period or any part of the period) a card was made out. The particulars required and the considerations that made them necessary were as follows :—

(1) *Member's name and initials, Approved Society number, and Membership number.* For identification purposes in case of queries arising as to other entries.

(2) *Sex, and in the case of women, civil state.* The sickness suffered by women differs from that of men, while that suffered by married women differs widely from that of single women (due in part to claims connected with maternity). It is thus necessary to separate the three groups. The date of marriage and/or widowhood was in addition, required so that if this date fell between 1921 and 1925 transference of the woman could be made from the single to the married group, or vice versa, at the appropriate date.

(3) *Date of birth.* This enables the exposed to risk to be classified according to age, an important point, as sickness is closely related to age, so that in an accurate comparison of the sickness experience of the various occupational groups the age distribution is a vital factor.

(4) *Date of entry into National Health Insurance, if after* 1*st January,* 1919 ; *date of entry into the particular Approved Society if after* 1*st January,* 1921 ; *and date of exit from the Approved Society if between* 1921 *and* 1925. The dates of entry allow calculation of the dates at which each member first became qualified for sickness benefits and disablement benefits, and thus enable the necessary correction to be made to the exposed to risk for those persons who were not already qualified for

benefit at the date at which the inquiry began. Under the Act each insured person has to be in insurance 26 weeks and to pay 26 contributions before becoming qualified to receive sickness benefit, and 104 weeks and to pay 104 contributions before becoming qualified to receive disablement benefit (the definitions of sickness and disablement are dealt with later). Where a person is not so qualified there would be a tendency, as no cash benefit could be drawn, not to notify the society of any sickness undergone. Accordingly, there is some doubt in such cases as to whether the sickness history is complete, and it is a safer policy not to include them amongst the exposed to risk, either for sickness or disablement until such date as they are fully qualified to draw benefit. The dates supplied allow this to be done with sufficient accuracy. To the date of entry given 6 months (26 weeks) was added and this date taken to be date of qualifications for sickness benefit; to secure the date of qualification for disablement benefit 2 years (104 weeks) was added to the date given. This method assumes continual employment from the time of entry into insurance, and is therefore obviously somewhat in error. This error was not considered by members of the trade to be sufficiently large to be of any importance. Any member who entered before 1st January, 1919, was, on this assumption, fully qualified at the beginning of the inquiry at 1st January, 1921. For members entering after this date adjustment was needed to their exposure to risk, as just explained. The date of entry into the particular Approved Society allows adjustment to be made for transfers, already fully qualified for benefits, coming into the Society during the inquiry. The date of exit similarly allows adjustment to be made for those who pass out of exposure during the period of inquiry. In calculating the duration of exposure of entries and exits one actuarial method is to assume that these are evenly spread over the year and that therefore the average exposure is six months. Inspection of the distribution of exits and entries proved that the assumption in this case was reasonable. The only exception was the Journalists' Society in the year 1921, when, owing to a new wage agreement which came into operation in 1920, large numbers of exits from the Approved Society took place in the early part of the year. These exits which therefore only related to persons exposed for the final few weeks of their "free year," were not included at all in the exposed to risk. The remainder of the exits in this Society were evenly spread and in all other societies the exits and entries were also evenly distributed. In addition in one or two cases calculation of the duration of exposure was made both on this assumption of an average of six months' exposure, and by a calculation of the actual days of exposure for the entries and exits. No material difference resulted in the total exposed to risk. This actuarial method has therefore been employed throughout, since it represents a considerable saving in time and labour and if the entries and exits are at all evenly spread gives an accurate result.

(5) The main requirement was *the invalidity experienced by each member during the* 5 *years,* 1*st January,* 1921, *to* 31*st December,* 1925. The details needed were dates at which sickness or disablement began and ended, precise nature of the incapacity including any change of diagnosis during incapacity, the distinguishing of "sickness" and "disablement" and the record, for this purpose, of "linked up" sicknesses previous to 1921.

The duration of each period of incapacity was then calculated so that the amount of morbidity suffered could be related to the exposed to risk, and analysis was made of it by cause of illness. Periods of incapacity coming under the Workmen's Compensation Act were excluded, as also were periods for which damages at Common Law were paid, since Approved Societies have not always full knowledge of these cases. This increases falsely the exposure to risk, since persons actually away from work are continued as exposed to risk, no notice being taken of these periods of incapacity. The error is not of any great magnitude. Where members suffered from very prolonged periods of sickness due to war service, the cards have been excluded, the sickness on them obviously having no bearing on occupational risks. Where an occasional short period of such incapacity has been recorded, the card has been retained and the sickness placed in the group entitled accidents and injuries. The number of such cases was relatively small.

Reference has been made several times to "sickness" and "disablement" and definition of these terms is required. This may be found in the National Health Insurance Acts. By the statutory provisions therein it is laid down that sickness benefit (15*s*. a week for a man, 12*s*. a week for a woman) is given only for a period or periods of sickness not exceeding 26 weeks. After 26 weeks' sickness benefit has been received, if illness still continues, it is termed disablement, and benefit is payable on a lower scale (7*s*. 6*d*. a week for a person of either sex). It has already been pointed out that an employed person becomes qualified for sickness benefit at an earlier date than that at which qualification for disablement benefit is reached, and this difference naturally produces a disparity in the numbers exposed to risk of sickness and exposed to risk of disablement. It would be possible to combine the two if the population exposed to risk was limited only to those who were qualified for both benefits. This would, however, reduce the number exposed and eliminate a certain amount of the incapacity experienced, and the better plan is to calculate the two rates separately.

Under the terms of the Act sickness benefit begins on the fourth day of incapacity, unless the claimant has received sickness benefit within the previous twelve months. In the latter case the illness is termed a "linked-up" sickness, and benefit begins on the *first* day of incapacity. In calculating the 26 weeks' duration of sickness, after which disablement benefit begins, such linked-up sicknesses are counted as one, i.e. the second illness is treated as a continuation of the first, so that the 26 weeks' maximum may be reached by a series of short linked-up sicknesses. A break of twelve months between sicknesses is required to nullify this process of linking up.

In calculating the duration of sickness experienced in this inquiry, *the date of onset of illness* has been taken and *not* the date at which benefit first became payable. In cases of sickness not linked-up, benefit is not payable till the fourth day of incapacity, while if linked-up it is payable on the first day; but for the purposes of calculation of duration of sickness in this investigation, the first day of incapacity in either case was the date adopted. It must be observed that the provisions of the Act tend to exclude sicknesses of less than three days' duration, except where such sickness is linked-up with a previous one, so that the total amount of incapacity recorded is a little in defect of the true amount suffered.

After this description of the methods adopted in calculating the exposed to risk, and in treating the sickness history, it remains to relate the one to the other. This is carried out in the following sections where the sickness for all causes and for certain cause groups is discussed both for all printers and for the various occupational groups of printers.

THE OCCUPATIONAL GROUPING.

The occupational grouping adopted is as follows :—

(1) *Composing department,* which includes both hand and machine compositors (linotype and monotype machine operators); in this group also are the correctors of the press—reading assistants, copyholders and the like. These latter are relatively very few in number. The total number of persons coming under observation in this group is 14,507, of whom 2,564 were entries and 2,610 were exits during the period under review (1921–25).

(2) *Machine department,* which includes machine-minders, or managers, and their assistants (including assistants on lithographic

machines), feeders and layers-on, and minders of such machines as the platen. Of these there come under observation 6,901, of whom 1,083 were entries and 847 were exits during 1921–25.

(3) *Stereotyping and Electrotyping department,* which includes electrotypers and stereotypers and their assistants. Of these there are 1,563, of which 458 were entries and 178 exits during 1921–25.

(4) *Bookbinding and ruling department,* which includes bookbinders and their assistants, gold blockers, leather workers and all workers of such type relating to bookbinding ; in addition are included machine rulers. Of these there are 3,836, of whom 455 were entries and 804 were exits during 1921–25.

(5) *Warehouse and cutters' department,* which includes packers, storekeepers, despatchers, printers' warehousemen and assistants, and all types of cutters—box, guillotine, etc. Of these there are 2,316, of whom 400 were entries and 339 were exits during 1921–25.

(6) *Typefounding department,* which includes foundry workers, stereocasters, and monotype casters and assistants. Of these are only 105—38 being entries and 8 being exits during 1921–25.

The *Lithographic department* was divided into two groups.

(7) *Lithographic printers,* which includes the managers of lithographic printing machines. The assistants on these machines belong mainly to the Society of Operative Printers and their Assistants, but are not there specified as such and so have had to be included with the letterpress machine group. Of lithographic printers there are 3,741, of whom 497 were entries and 617 were exits during 1921–25.

(8) *Lithographic artists,* which includes litho-designers, engravers, photographers, photo-etchers, process artists, and the like. Of these there are 2,119, of whom 675 were entries and 760 were exits during 1921–25.

(9) *Journalists,* 960 in number, 188 being entries and 512 being exits during 1921–25.

These last two groups, the lithographic artists and the journalists, bear a different relationship to National Health Insurance from that of the other workers. Lithographic artists and journalists are not manual workers under the terms of the National Health Insurance Acts, so that they automatically cease to be insured when their income exceeds the limit fixed by the Acts for non-manual workers. (The high proportion of exits is obvious in Table III.) No such clause is operative for the other printers, who being " manual workers " remain in insurance so long as they are employed, irrespective of their income. In case this differentiation should have any effect upon the relative sickness rates (e.g. the non-manual workers in later age groups might have remained in insurance through mental or physical inability to reach higher incomes), it has been thought wiser to keep the non-manual workers entirely distinct from the main group of manual workers. Accordingly, the lithographic artists and the journalists are *not* included amongst the total entitled "all printers." This group, as shown in Table III, which summarises the information just given, comprises the compositors, machine-men, stereotypers and electrotypers, warehousemen and cutters, bookbinders and machine rulers, typefoundry workers and monocasters, and lithographic machine printers.

TABLE III.—*The Occupational Groups of Printers examined ; the numbers coming under observation in each, together with the numbers of entries and exits over the period of investigation,* 1921–25.

Occupational Group.	Total Number of persons coming under observation during 1921–25*	Entries during 1921–25.	Exits during 1921–25.
Compositors	14,507	2,564	2,610
Machinemen..	6,901	1,083	847
Stereo and electrotypers ..	1,563	458	178
Bookbinders and rulers ..	3,836	455	804
Warehousemen and cutters	2,316	400	339
Typefoundry workers and Monotype casters ..	105	38	8
Lithographic printers ..	3,741	497	617
All printers	**32,969**	**5,495**	**5,403**
Journalists	960	188	512
Lithographic artists ..	2,119	675	760

* This is the number of persons found to be members of the Approved Societies at 1st January, 1921, plus the persons who became members (the entries) between 1st January, 1921 and 31st December, 1925. This number thus includes both the entries and exits and simply shows the grand total of persons included in the inquiry over the 5 years.

It is not possible to compare accurately this distribution of operatives in the occupational groups with that given by the 1921 census. For in the latter 17,542 workers are only labelled "printers," 7,902 "other skilled workers," and 6,275 "other workers." Such ill-defined headings were obviated in this inquiry. Using only the more clearly defined groups it was found that the compositors, machine printers (including lithographic machine printers), stereotypers and electrotypers, and bookbinders and rulers in this inquiry represent between 40 and 50 per cent. of the census population. Warehousemen are about 30 per cent. of the census population. These numbers can at the best be only very approximate for the reason given above and also because the Approved Societies contained some Scotch and Irish members.

THE INCIDENCE OF SICKNESS AND DISABLEMENT AMONGST PRINTERS COMPARED WITH THE INCIDENCE AMONGST A SAMPLE OF THE GENERAL INSURED POPULATION FOR THE YEARS 1921–23.

Before turning to the experiences of the separate occupational groups it will be of some interest to examine the sickness incidence amongst printers as a whole. It is possible to compare this incidence with the sickness rates suffered by what may be termed a " standard population."

For the years 1921–23 a Departmental Actuarial Committee presented to the Royal Commission on National Health Insurance a full statement of the experience of a group of Approved Societies. These societies were " so chosen as to constitute as nearly as may be in respect of each sex, a microcosm of the whole insured population." They included some 500,000 men and 400,000 women. The material was collected and tabulated by the Ministry of Health, and the actuarial analysis was made in the Government Actuary's Department. The experience is known as the " Selected Societies Experience," and the data are presented in an appendix to the Report of the Royal Commission on National Health Insurance.* In addition, Sir Alfred Watson, the Government Actuary, has given these data in less detailed form, but together with much other information, in a paper printed in the journal of the Royal Statistical Society.†

Taking these figures as representative of the sickness experienced by the whole insured population, it will be possible to see whether printers are more or less favourably placed than the "general" insured population of the country. Since sickness incidence varies considerably from year to year, it would be inadvisable to use the whole of the data relating to the printers in comparison with those relating to the Selected Societies, since the former represent the experience of 1921–25 and the latter that of 1921–23. The sickness figures for the printers have therefore been taken out separately for the years 1921–23, so that the rates are strictly comparable with those of the Selected Societies. The comparison is set out in Table IV relating to " sickness " (first 26 weeks of incapacity) and in Table V relating to " disablement " (incapacity continuing after first 26 weeks). The actual figures from which the Selected Societies' rates are derived are not given here, but the exposed to risk was very large —about 1½ million years of life of all ages, so that there is no doubt as to the significance of the rates.

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* Cmd. 2596. 1926.

† *J Roy Stat. Soc.* 90, 3 (1927). The rates for the Selected Societies quoted in this report have been taken from this source. They differ slightly from the figures given in the Departmental Committee's report since adjustment has been made by Sir Alfred Watson to include the first three days of sickness. The rates are given in his paper in weeks; they have been multiplied here by 7 to convert them into days, whereas only working days were actually recorded.

In columns (2), (3) and (4) are given the figures for the printers of the actual number of days of sickness experienced in each age group (quinquennial groups), the number of claims made and the total number of person-years of exposure to risk.* The latter figure enables some estimate to be made of the reliability of the rates. The number of days of sickness suffered per person-year of exposure is the only rate which can be used for comparison. The number of claims made and the duration of sickness per claim are not comparable with the rates of the same type given for the Selected Societies, since the definition of the term " claim " differs in the two experiences. In the printing inquiry, dealing with the medical aspect of incapacity, each period of sickness was defined as a claim, irrespective of whether it was " linked-up " with a previous period of sickness or not ; in the Selected Societies' experience, dealing mainly with the financial aspect, two or more periods of sickness within the same calendar year were counted as only one claim. This makes the printers' claims more numerous than they should be for true comparability.

Turning to Table IV and comparing column (5) with column (6) it will be seen that the printers occupy a distinctly more favourable position than does the general insured population in the Selected Societies, with the exception of the first age group where the two rates are nearly on a par. Judged by the percentages given in column (7), the printers have from age 20 to age 64 only, roughly, three-quarters of the amount of short-period sickness suffered by this general population representative of the whole insured population.

An additional point of contrast is to be observed in the movement of the rates up to age 34. In the Selected Societies the rate rises slightly between entrance into insurance, at 16–19 years, and the age group 20–24 years, between 20 and 29 it is stationary but rises again in the age group 30–34. For the printers there is an initial high rate—a rate which is not attained again until twenty-five years of age have passed and the group 40–44 is reached. Between 16–19 and 30–34 there is a slow but steady fall in sickness incidence, and expressed as a percentage of the Selected Societies' experience the fall is from 96 per cent. to as low as 64 per cent. It is a point of some interest that this movement of the printers' rates in the younger age groups bears a distinct resemblance to the movements revealed in older experiences. In the Manchester Unity 1893–7 experience there is the same high rate in the first age group, followed by a fall, reaching a minimum at age 24, and the level of the initial rate is not again attained until age 38.

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* The exposed to risk has to be given in this form, since it is made up of so many persons exposed for the whole period and so many (entries and exits) exposed for only a part. The addition of these two gives " person-years " ; in other words, 100 person-years of exposure are the equivalent of 100 persons exposed for one year, though actually they are composed of more than 100 persons exposed for varying durations, some for a whole year and some for less

In Table V dealing with disablement this point of contrast is not to be seen. With the exception of the age group 35–39, the rate rises steadily throughout the insured life. The printers, again, are in the most unfavourable position in the first age group. Here their rate is 35 per cent. in excess of that for the Selected Societies. It must be noted, however, that in this group the disablement is very small in amount and in number of claims, and too much faith should not be placed upon the absolute level of the percentage. More cannot be said than that the printers have some disadvantage in the initial years of insurance, and that this is apparent both for sickness and for disablement, somewhat more distinctly in the latter. From 20 to 29 years of age the rates for printers and the Selected Societies are (taking the exposure and absolute amounts into account) approximately level. In age group 30–34 there is an abrupt rise in the disablement rate for printers, placing it 23 per cent. above that for the Selected Societies, but this rise is only a random fluctuation due to the relative smallness of the sample. The excess is due actually to the presence in the group of four totally incapacitated persons. Such an excess might easily arise, and has here arisen, by chance, and therefore has no significance. The rate falls again in the following age group, and in that group and for the rest of insured life the printers hold the advantage. Their disablement experience is thereafter consistently below that of the Selected Societies, at an average level of about four-fifths of the Selected Societies' rates.

To sum up, the conclusions derived from this comparison of the printers with the Selected Societies may be stated as :—

(1) Relative to their experience in later life the printers have high rates from sickness and from disablement in the first years of insurance, i.e. at 16–19 years of age, and compared with the general insured population they occupy their most unfavourable position in this age group.

(2) In later age groups they are for short-period incapacity at a distinct advantage throughout insured life, their rates of sickness being roughly only three-quarters of those for the general insured population.

(3) For long-period incapacity this position of advantage is not reached till later in life—in the age group 35–39. From 20–29 years there is no appreciable difference between the rates of printers and those of the general insured population. At ages 30–34 the printers experience a sudden increase of incapacity, but this is a random fluctuation due to the paucity of the data and is not significant. From that point on to the concluding age printers have approximately only four-fifths of the disablement suffered by the general insured population.

TABLE IV.—*Sickness (first 26 weeks) amongst all Printers compared with that experienced by the Departmental Committee's Selected Societies, for the years* 1921–23.

Age group (1)	Person-years of exposure for sickness. (2)	Total duration of sickness in days.* (3)	Number of sickness claims † (4)	Sickness rate in days per person-year		Printers' rate as percentage of Selected Societies' rate. (7)
				Printers (5)	Selected Societies. (6)	
16–19	4,414·0	18,683	824	4·23	4·41	96
20–24	4,997·5	17,780	714	3·56	4·69	76
25–29	7,456·5	25,152	989	3·37	4·69	72
30–34 . . .	10,458·0	33,237	1,351	3·18	4·97	64
35–39	10,385·5	38,653	1,465	3·72	5·25	71
40–44 . .	10,590·0	44,767	1,520	4·23	5·60	76
45–49 . . .	10,995·5	52,892	1,793	4·81	6·30	76
50–54 . . .	9,318·5	51,822	1,684	5·56	7·70	72
55–59 . . .	6,838·5	46,241	1,364	6·76	9·73	69
60–64	4,195·0	41,675	1,021	9·93	12·95	77

* In calculating the duration of sickness, the *whole* duration of each period of incapacity is used throughout all the tables in this report, i e the first three days for which benefit is not payable *are* included.

† A claim is here and throughout defined as a single period of sickness, irrespective of whether it is "linked-up" (under the terms of the National Health Insurance Acts) with a previous period or not. In addition, since the experience was analysed in separate calendar years and the three years then totalled, it follows that a single period of incapacity that fell into two calendar years is counted for the 1921–23 period as *two* claims.

TABLE V.—*Disablement (incapacity after the first 26 weeks) amongst all Printers compared with that experienced by the Departmental Committee's Selected Societies for the years* 1921–23.

Age group. (1)	Person-years of exposure for disablement (2)	Total duration of disablement in days. (3)	Number of disablement claims (4)	Disablement rate in days per person-year.		Printers' rate as percentage of Selected Societies' rate. (7)
				Printers (5)	Selected Societies (6)	
16–19*	2,301·5	1,947	17	·85	·63	135
20–24 . .	4,962·5	6,300	47	1·27	1·19	107
25–29	7,374·5	12,858	69	1·74	1·75	99
30–34	10,352·5	26,844	133	2·59	2·10	123
35–39 .	10,294·5	22,016	118	2·14	2·73	78
40–44 .. .	10,511·0	31,862	174	3·03	3·36	90
45–49	10,921·0	39,139	198	3·58	4·27	84
50–54 .. .	9,270·5	39,570	217	4·27	5·53	77
55–59 ..	6,808·0	49,478	233	7·27	9·87	74
60–64	4,173·0	66,724	311	15·99	17·78	90

* No sickness benefit is payable till six months after entry, and no disablement benefit till two years after entry. Exposure, it has been pointed out, has not been begun till these dates, so that the earliest age at which sickness can take place is 16½ years, and the earliest age for disablement 18 years

The disadvantage of printers thus shown in amount of incapacity suffered in the first years of employment is in accordance with the death-rates for the same years, 1921–23, as shown in Table I Here, also, in age group 15–19 the printers are more unfavourably placed than at any other period of life.

THE INCIDENCE OF SICKNESS AND DISABLEMENT AMONGST ALL PRINTERS AND AMONGST EACH OCCUPATIONAL GROUP OF PRINTERS FOR THE YEARS 1921–25.

Further investigation of these differences found between the printers and the general insured population may be made by analysis of the data relating to each occupational group The data relating to these groups cannot be compared in detail, however, with the experience of the Selected Societies, since not only does this confine the data to the years 1921–23 and exclude two years of the experience examined for the printers, but also it does not allow the " claim-rate " to be discussed or cause of sickness to be used. Instead, the figures for the whole five years, 1921–25, will now be utilised and it will be determined what quota each occupational group contributes to the various incapacity rates found for printers as a whole. As a preliminary the rates for all printers are set out for 1921–25 in Tables VI and VII, and are shown graphically in Figs. 1 and 2. These tables are continued to age 69, whereas those relating to 1921–23 stopped at age 64, no data being given for the Selected Societies for the age group 65–69. In addition, the claim-rate has now been included, which was excluded from the 1921–23 table owing to lack of comparability with the Selected Societies' data (as was pointed out on p. 17).*

Comparing the sickness and disablement rates for 1921–25 in Tables VI and VII with those for 1921–23 in Tables IV and V, it will be seen that the rates for the longer period are, with a single exception, uniformly slightly higher than those for the shorter period. In other words, the years 1924 and 1925 were years with a greater incapacity experience than were 1921–23. The single exception is in the age-group 30–34 for disablement, the group in which for 1921–23 the abrupt jump in the disablement rate was observed. This sudden rise and subsequent fall, which, it was pointed out, is only a sampling error due to small numbers, are still apparent for 1921–25, but somewhat less distinctly so than in the 1921–23 experience. The larger amount of data provided by the five years' experience reduces the random fluctuation.

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* The sickness was analysed in calendar years and then totalled for the five years Thus, if a claim ran into two years it was counted twice —once in each year, and will appear as two in the total. If this method is not followed the disadvantage of overlapping age groups results.

In the claim-rate for sickness is revealed the same very high initial rate (21·24 per 100 person-years) as is seen in the days-rate. From age 20 to 44 the claim-rate remains at a substantially lower level (between 14 and 16 per 100 person-years) and it is not until as late as age 55–59 that so high a rate is again reached (22·72 per 100 person-years). It may be mentioned in passing that the claim-rate for sickness amongst printers for 1921–23 was in every age group but the first lower than the corresponding rate for the Selected Societies Since the definition of claim in the printing investigation produces an excess of claims compared with the definition used in the Selected Societies experience, the claim-rate found amongst printers must in reality be still lower in true comparison. The sickness rates found are therefore due, at least in part, to a smaller number of claims made by printers than are made by the general insured population, although no absolute figure can be put to this advantage. The disablement claim-rate shows no such uniform defect and no statement is therefore possible as to its relative position.

The disablement claim-rate rises steadily throughout life; relatively to the corresponding sickness rate, it is negligible in the first few years, but from 60–69 disablement claims form a substantial part of all claims and the days of incapacity suffered exceed, as would be expected, those produced by the larger number of cases of short-period sickness.

In Tables VIII to XIX and Figs. 1 to 4 are set out similar rates for each occupational group both in absolute form and also expressed as percentages of the rates for all printers. For these occupational groups, rates for all ages have been calculated for days of incapacity and for number of claims, and are given in two forms, as crude rates and as standardised rates. Some explanation of these terms is required. The crude rate is reached merely by dividing the total amount of sickness or total number of claims experienced at all ages by the total number of persons exposed to risk at all ages. For example, in the table relating to compositors, Table VIII, the crude rates, 5·11 days of sickness per person-year of exposure and 17·68 claims per 100 person-years of exposure, are reached by dividing the total duration of sickness suffered, 302,602 days, and the total number of claims made, 10,468, by the total exposure to risk, 59,205·0 person-years. Such crude rates, e.g. the compositors' crude rates and the machinemen's crude rates, cannot be compared one with another *unless the distribution of the two populations over the various age groups is similar.* As invalidity increases with age there will be more illness in a population made up of old people than there will be in one consisting mainly of young people, and the nature of the sickness suffered will vary too. Hence, the fallacy of the crude rate, which takes no account of the preponderance of population that may exist in any age group. For instance, if, in the sample populations here dealt with, there was a preponderance of compositors in the older age groups while machinemen tended to concentrate

TABLE VI.—*Sickness (first 26 weeks) amongst All Printers for the years* 1921–25. *All Causes.*

Age group. (1)	Person-years of exposure for for sickness. (2)	Total duration of sickness in days. (3)	Number of sickness claims. (4)	Sickness rate in days per person-year (5)	Number of sickness claims per 100 person-years of exposure. (6)
16–19	8,648·0	40,471	1,837	4·68	21·24
20–24	8,059·0	29,156	1,234	3·62	15 31
25–29	11,469 0	39,872	1,653	3 48	14 41
30–34	16,634 5	58,945	2,445	3·54	14·70
35–39	17,140·5	67,481	2,686	3·94	15 67
40–44	17,147 5	76,488	2,731	4·46	15 93
45–49	18,144·0	93,385	3,239	5 15	17·85
50–54	16,004·0	97,456	3,251	6·09	20 31
55–59	11,844·0	88,118	2,691	7·44	22·72
60–64	7,424·0	76,111	1,948	10·25	26·24
65–69	3,978·5	63,700	1,327	16·01	33·35
All ages..	136,493·0	731,183	25,042	5·36	18·35

TABLE VII.—*Disablement (after first 26 weeks) amongst All Printers, for the years* 1921–25. *All Causes.*

Age group. (1)	Person-years of exposure for disablement. (2)	Total duration of disablement in days (3)	Number of disablement claims. (4)	Disablement rate in days per person-year (5)	Number of disablement claims per 100 person-years of exposure (6)
16–19	4,829·0	4,457	37	92	77
20–24	7,976·5	11,951	79	1·50	·99
25–29	11,340·0	21,186	113	1·87	1·00
30–34	16,457·5	38,388	192	2·33	1·17
35–39	16,962·0	38,373	215	2·26	1·27
40–44	16,998·0	52,188	280	3·07	1·65
45–49	18,013·5	69,819	364	3·88	2·02
50–54	15,898·0	76,595	424	4·82	2·67
55–59	11,780·5	86,308	424	7·33	3·60
60–64	7,374·5	129,079	590	17·50	8·00
65–69	3,961·5	153,492	652	38·75	16·46
All ages	131,590·5	681,836	3,370	5·18	2·56

in the younger age groups, then naturally judging from "all age rates" higher crude sickness and disablement rates would be expected amongst compositors than amongst machinemen. But it would be merely a reflection of the dissimilarity in age distribution.

The rates in each age group (as long as the groups are not too broad) are not open to this objection as in them obviously like is being compared with like. In the separate age groups, however, the populations at risk are sometimes relatively small, and therefore the rates are open to the chance fluctuations of sampling For this reason it is of value to secure as well a rate for all ages, which will have a greater stability due to greater numbers, and will, at the same time, take account of the differences in age distribution This is achieved by the use of the standardised rate The process is as follows

A population is selected which, in the age distribution of its components, may be termed " normal," e g the number in each group bears the same relationship one to another as do those in the total population, for instance, of England and Wales, so that compared with the "ordinary" population there is no undue preponderance in any one age group. The selection of the standard is, to a certain extent, arbitrary, as there can be no absolute definition of a "normal" population. The standard selected here is the exposed to risk for all printers (as given in column (2) in Tables VI and VII). To the numbers in each age group in this standard population is then applied the sickness rate (or disablement rate as the case may be) as found in the corresponding age group in each occupational division. For instance, the number exposed to risk aged 16–19 in the standard population, 8,648·0, is multiplied by 5·23, 4 27, 3·87, etc., the sickness rates in this age group amongst compositors, machinemen, stereotypers, etc This gives the number of days of sickness that a population of this size in this age-group would suffer if exposed to the same rate as is actually found in each type of occupation. The same process is carried out for each age group, and the amount of sickness thus given is totalled. This total divided by the total population at all ages in the standard population gives the standardised rate for each type of occupation These rates are directly comparable and represent the rates that would be found amongst populations identical in age distribution experiencing the various rates found in the separate age groups in the occupational groups.

In some cases the relations of the standardised rates differ quite appreciably from those of the crude rates, showing that the age distribution of population amongst the various occupations certainly differs. This can be seen too from a study of the exposed to risk.; by calculating the exposed to risk at ages in terms of percentages of total exposure at all ages, it was found, for example, that of compositors 54 per cent. are below age 45 and 46 per cent.

are 45 and over. Amongst machinemen, on the other hand, 62 per cent. are below 45 and 38 per cent. only are 45 and over. Thus, compositors tend to be older than machinemen and the crude rates are not comparable. By standardising, the compositors' rate is lowered (from 5·11 to 4·86), the machinemen's rate is increased (from 6·05 to 6·42).

Turning now to Tables VIII to XXI and Figs. 1 to 4, the following conclusions are reached :—

(1) *Compositors* (Tables VIII and IX, XX and XXI and Figs. 1 and 2).—The initial high sickness rate at ages 16–19 observed for all printers is still more distinct amongst these workers. For all printers the number of days of sickness per person-year is 4·68 in this age group ; for compositors it is 5·23, or 112 per cent. of the all printers' rate. The excess is made up partly by more numerous claims, the compositors' claim rate being 104 per cent. of that for all printers, and partly by a longer duration for each claim, 23·6 days as compared with 22·0 days for all printers. At ages 20–29 there is no great difference between all printers and this occupational group. The fall in the amount of sickness suffered is apparent for both, but it becomes more accelerated amongst the compositors, and from age 30 to 64 the latter experience fewer days of sickness and fewer claims than do all printers. Taken as a whole, they have 91 per cent. of the days of sickness and 94 per cent. of the claims of all printers, and in most age groups the length of time that their sicknesses last is shorter.

In disablement experience their excess in the first age group is very distinct ; at 20–29 they have lower rates ; at 30–34 there is an abrupt rise in the days rate—the random fluctuation that has already been referred to in discussing the data for all printers—followed by a falling back again in the next age group, the rates remaining appreciably below those for all printers throughout middle age, from 35 to 54. At ages 55–64, judging by both days rate and claim rate, there is no great difference ; in the final group, 65–69, the compositors are again inferior to all printers. Taken as a whole, they have 99 per cent. of the days of disablement and 91 per cent. of the claims of all printers, while the duration per claim is somewhat longer in nearly all age groups.

(2) *Machine Printers* (Tables X and XI, XX and XXI, and Figs. 1 and 2).—Amongst these workers the initial high rate is less definite, and they are slightly better off as regards sickness than all printers. From 20 to 24 there is little difference between them, but throughout the rest of insured life the machine printers occupy, compared with all printers, a distinctly unfavourable position both as to days of sickness and number of claims, and, until the final two age groups, in length of claim. For the group as a whole the day rate is 20 per cent. above that for all printers and the claim rate is 14 per cent. in excess.

In disablement the rates fluctuate erratically. (To secure stability a much larger exposure to risk is required than is for sickness, since the number of claims is far less and their duration being long an additional claim or two makes an appreciable difference to the rates.) The initial rate is distinctly lower than for all printers, for the rest of the age groups the day rate fluctuates above and below that for all printers, but the claim rate is consistently above between ages 20 and 59. On the other hand, the length of claim made is shorter than for all printers. Taking all ages together, this group has 96 per cent. of the days of disablement and 110 per cent. of the claims of all printers.

(3) *Stereotypers and Electrotypers* (Tables XII and XIII, XX and XXI, and Figs. 1 and 2).—The number exposed to risk for this occupational group is somewhat small The initial high rate is present but on a considerably lower scale than for all printers. Taking all ages together their days of sickness are about the same as those for all printers (101 per cent.), but their claims are slightly in excess (109 per cent.). The length of claim made is therefore shorter than for all printers. In disablement they have appreciably less in volume—only 79 per cent. of all printers, but approximately an equal number of claims—102 per cent of all printers at all ages, the duration per claim being consequently significantly shorter.

(4) *Bookbinders and Machine Rulers* (Tables XIV and XV, XX and XXI, and Figs. 3 and 4).—These workers share in the initial high rate, being in the first age group nearly on a par with all printers Taken as a whole, however, it may be seen that they have distinctly lower rates throughout life both as to days of sickness and number of claims. Their standardised rates are only 87 per cent. (days of sickness) and 80 per cent. (number of claims) of those for all printers, but, on the other hand, their duration per sickness exceeds that of all printers in nearly every age group. In long period incapacity, on the other hand, they lose these relatively low day and claim rates. The absolute level of the rates in the different groups should not have, in view of the smallness of the exposure, much importance attached to them. It will be seen that they move first up and then down in meaningless fashion, suggesting only the fluctuations of sampling due to small numbers. Using the standardised rates as more reliable evidence, it is seen that these bookbinders and rulers have 12 per cent. excess in days of disablement per person-year and 9 per cent. excess in claims. These claims are again, on the whole, of longer duration.

(5) *Warehousemen and Cutters* (Tables XVI and XVII, XX and XXI, and Figs. 3 and 4).—This group does not contribute its full share to the initial high rate. The day rate at 16–19 is only 79 per cent. of that for all printers though the claim rate reaches 96 per cent. With the exception of the following age group, 20–24, these workers have definitely higher rates throughout working life both as to days of sickness, number of claims, and length of claim.

The divergence is quite distinct and results in standardised rates 117 per cent. (day rate) and 108 per cent. (claim rate) of those for all printers.

In disablement the warehousemen and cutters start again with low rates, have relatively high rates at ages 25–54, and exceedingly low rates at 55–69. Again, owing to the small number exposed to risk in this group, the rates are not reliable. Judging by the standardised rates for these operatives and for all printers there is no very significant difference between the two, day rate 4·96 against 5·18 ; claim rate 2·79 against 2·56.

(6) *Lithographic Machine Printers* (Tables XVIII and XIX, XX and XXI, and Figs. 3 and 4).—The days of sickness for these operatives fluctuate considerably from group to group. They do not show the uniformly high rates of the other group of machine printers, though their claims are in excess in nearly every age group. Apart from the age group 20–24, they do not in days of sickness deviate at all widely from the rates for all printers. For all ages their rate is virtually equal to that for all printers, while their claims show an excess of 9 per cent. As a whole their claims are of relatively short duration.

In disablement they again show rather meaningless fluctuations the result for all ages being that no material difference is shown between them and all printers.

(7) *Typefounders and Casters.*—This group is too few in number to be treated separately. It is included in " all printers," however.

(8) *Journalists.*—No table is given for this group as analysis of the data suggests that the figures are quite unreliable. In sickness the rates are far lower than those for the other classes, in several age groups being negligible. On the other hand, disablement is somewhat in excess, the standardised day rate being 134 per cent. of that for all printers. The undoubted reason for the absence of short-period incapacity is that their employers continue to pay their wages during sickness of short duration, so that the members have no incentive to claim benefit from the Approved Society. On the other hand, those who become permanently incapacitated are compelled to have recourse to their society and the disablement rate accordingly does not show a similar defect. Rather does it suggest an excess of long-period incapacity amongst these workers, but the figures show very wide fluctuations in the age groups. They cannot on the whole be considered as satisfactory and no importance can be attached to them.

(9) *Lithographic Artists.*—No tables are given for these workers as, like journalists, they do not come under the term " manual worker " in the sense of the National Health Insurance Acts. The fact that members who reach a certain income level automatically pass out of the experience lays the figures open to the

suspicion of selection—the less able and perhaps less physically fit tending to remain within the insured class For this reason the figures cannot be regarded as entirely satisfactory, and somewhat random fluctuations in the rates at ages make them still less so. Actually the standardised rates give these workers somewhat less sickness than all printers (76 per cent. of days of sickness and 93 per cent of claims) while their disablement rates are approximately equal to those for all printers (101 per cent. of days of disablement and 95 per cent. of claims). Again, no great importance should be attached to these figures, and it is not proposed in this report to deal any further with these two groups, the journalists and the lithographic artists.

The comparison that has thus been carried out shows definitely the varying contributions that each occupational group makes to the sickness experience of the whole. On the other hand, it does not bring out so distinctly the range of differences between the groups. For instance, compositors in comparison with *all* printers showed low sickness rates ; in comparison with *other* printers (less compositors), they would show still more favourable rates since compositors form nearly half the total of all printers and accordingly play a very large part in producing the rates for all printers.

For facility of such a comparison of the various occupational groups the rates of sickness and disablement (days and claims) have been collected from Tables VII to XIX and brought together in Tables XXII and XXIV, while in Tables XXIII and XXV the rates for each group are expressed as percentages of the corresponding rates for compositors. The relative positions of the groups are shown diagrammatically in Fig 5. In Table XXII the high sickness rate of the compositors at age 16–19 stands out clearly—5·23 days against 4·27 days for machine printers, 3·87 days for stereotypers, 4·43 days for bookbinders, 3·71 days for warehousemen, and 4·13 days for lithographic printers In the claim rate in this age group their excess is similarly distinct over all occupational groups except the stereotypers.

The very favourable position that the compositors and bookbinders occupy from age 25–64 is apparent, while the high rates which the machine printers and warehousemen suffer become obvious in this comparison—shown perhaps more clearly in Table XXIII, where the consistently high percentages after age 25 are striking. These percentages show more clearly, too, the larger number of claims that are made by stereotypers and electrotypers and by lithographic machine printers in comparison with compositors. In days of sickness the standardised rates show an excess also for these groups, but the percentages in the age groups are erratic and give no clear answer.

In the disablement tables (XXIV and XXV) each individual figure must be regarded with extreme caution and only the general tenour discussed

Table VIII.—*Sickness (first 26 weeks) amongst Compositors compared with that experienced by All Printers for the years 1921–25.*

Age Group.* (1)	Person-years of exposure. (2)	Total duration of sickness in days. (3)	Number of sickness claims (4)	Compositors.		All Printers		Compositors' rates as percentage of All Printers' rates	
				Day rate † (5)	Claim rate ‡ (6)	Day rate.† (7)	Claim rate ‡ (8)	Day rate. (9)	Claim rate. (10)
16–19	3,936·5	20,578	872	5·23	22·15	4·68	21·24	112	104
20–24 .	3,130·0	11,128	487	3·56	15·56	3·62	15·31	98	101
25–29	4,759·5	15,821	693	3·32	14·56	3·48	14·41	95	101
30–34 .. .	6,900·0	21,059	882	3·05	12·78	3·54	14·70	86	87
35–39 . ..	6,326·5	21,135	959	3·34	15·16	3·94	15·67	85	97
40–44	6,679·0	22,989	933	3·44	13·97	4·46	15·93	77	88
45–49	7,910·5	36,849	1,319	4·66	16·67	5·15	17·85	90	93
50–54	7,501·0	39,098	1,388	5·21	18·50	6·09	20·31	86	91
55–59	5,918·0	40,280	1,256	6·81	21·22	7·44	22·72	92	93
60–64	3,909·5	37,727	963	9·65	24·63	10·25	26·24	94	94
65–69	2,234·5	35,938	716	16·08	32·04	16·01	33·35	100	96
All Ages—									
Crude ..	59,205·0	302,602	10,468	5·11	17·68	5·36	18·35	—	—
Standardised				4·86	17·26	5·36	18·35	91	94

* Age last birthday at beginning of year of exposure.
† In days per person-year of exposure.
‡ In claims per 100 person-years of exposure.

TABLE IX.—*Disablement (after first 26 weeks) amongst Compositors compared with that experienced by All Printers for the years* 1921–25.

Age Group.* (1)	Person-years of exposure (2)	Total duration of disablement in days (3)	Number of disablement Claims (4)	Compositors: Day rate † (5)	Compositors: Claim rate ‡ (6)	All Printers: Day rate † (7)	All Printers: Claim rate ‡ (8)	Compositors rates as percentage of All Printers' rates: Day rate (9)	Compositors rates as percentage of All Printers' rates: Claim rate. (10)
16–19	2,173·0	3,197	20	1·47	·92	·92	·77	160	119
20–24	3,102·0	3,231	23	1·04	·74	1·50	·99	69	75
25–29	4,705·5	7,598	36	1·61	·77	1·87	1·00	86	77
30–34	6,809·0	17,112	70	2·51	1·03	2·33	1·17	108	88
35–39	6,234·0	12,634	64	2·03	1·03	2·26	1·27	90	89
40–44	6,597·0	15,195	77	2·30	1·17	3·07	1·65	75	71
45–49	7,845·0	26,971	136	3·44	1·73	3·88	2·02	87	86
50–54	7,441·0	23,505	133	3·16	1·79	4·82	2·67	66	67
55–59	5,878·0	45,634	194	7·76	3·30	7·33	3·60	106	92
60–64	3,874·0	70,819	308	18·28	7·95	17·50	8·00	104	99
65–69	2,224·0	105,004	425	47·21	19·11	38·75	16·46	122	116
All Ages—									
Crude	56,882·5	330,900	1,486	5·82	2·61	5·18	2·56	99	91
Standardised				5·12	2·33	5·18	2·56		

* Age last birthday at beginning of year of exposure.
† In days per person-year of exposure.
‡ In claims per 100 person-years of exposure

TABLE X.—*Sickness (first 26 weeks) amongst Machine Printers compared with that experienced by All Printers for the years* 1921–25

Age Group.*	Person-years of exposure	Total duration of sickness in days	Number of sickness claims	Machine Printers.		All Printers		Machine Printers' rates as percentage of All Printers' rates.	
				Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate	Claim rate.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
16–19	1,962·5	8,378	400	4·27	20·38	4·68	21·24	91	96
20–24	1,812·5	6,450	265	3·56	14·62	3·62	15·31	98	95
25–29	2,164·5	8,736	342	4·04	15·80	3·48	14·41	116	110
30–34	3,545·5	16,407	624	4·63	17·60	3·54	14·70	130	120
35–39	4,559·5	19,687	754	4·32	16·54	3·94	15·67	110	106
40–44	4,555·0	27,173	875	5·97	19·21	4·46	15·93	134	121
45–49	4,037·0	26,479	852	6·56	21·10	5·15	17·85	127	118
50–54	3,255·5	24,401	778	7·50	23·90	6·09	20·31	123	118
55–59	2,091·5	20,301	581	9·71	27·78	7·44	22·72	131	122
60–64	1,080·5	12,020	332	11·12	30·73	10·25	26·24	108	117
65–69	461·5	8,587	182	18·61	39·44	16·01	33·35	116	118
All Ages—									
Crude	29,525·5	178,619	5,985	6·05	20·27	5·36	18·35	120	114
Standardised				6·42	20·95	5·36	18·35		

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure.

‡ In claims per 100 person-years of exposure.

TABLE XI.—*Disablement (after first 26 weeks) amongst Machine Printers compared with that experienced by All Printers for the years* 1921–25.

Age Group.* (1)	Person-years of exposure. (2)	Total duration of disablement in days (3)	Number of disablement claims. (4)	Machine Printers.		All Printers.		Machine Printers' rates as percentage of All Printers' rates	
				Day rate † (5)	Claim rate ‡ (6)	Day rate.† (7)	Claim rate.‡ (8)	Day rate. (9)	Claim rate. (10)*
16–19	1,087·0	725	6	·67	·55	·92	·77	73	71
20–24 ..	1,788·0	2,740	23	1·53	1·29	1·50	·99	102	130
25–29 .. .	2,130·5	3,851	22	1·81	1·03	1·87	1·00	97	103
30–34 ..	3,523·0	8,368	50	2·38	1·42	2·33	1·17	102	121
35–39	4,530·0	11,620	65	2·57	1·43	2·26	1·27	113	113
40–44 .. .	4,534 0	12,536	78	2 76	1·72	3·07	1·65	90	104
45–49	4,020·0	15,796	100	3·93	2·49	3·88	2·02	101	123
50–54 . ..	3,250·5	21,946	127	6·75	3·91	4·82	2·67	140	146
55–59	2,083·5	13,715	92	6·58	4 42	7·33	3·60	90	123
60–64 . .	1,076·0	13,583	70	12·62	6·51	17·50	8·00	72	81
65–69 .	460·5	16,615	73	36·08	15 85	38·75	16·46	93	96
All Ages—									
Crude ..	28,483·0	121,495	706	4·27	2·48	5 18	2·56	96	110
Standardised				4·99	2·82	5·18	2·56		

* Age last birthday at beginning of year of exposure

† In days per person-year of exposure.

‡ In claims per 100 person-years of exposure.

TABLE XII.—*Sickness (first 26 weeks) amongst Stereotypers and Electrotypers compared with that experienced by All Printers for the years* 1921–25.

Age Group.*	Person-years of exposure	Total duration of sickness in days.	Number of sickness claims.	Stereotypers and Electrotypers.		All Printers.		Stereotypers and Electrotypers' rates as percentage of All Printers' rates	
(1)	(2)	(3)	(4)	Day rate.† (5)	Claim rate.‡ (6)	Day rate.† (7)	Claim rate ‡ (8)	Day rate. (9)	Claim rate. (10)
16–19	468·5	1,815	105	3·87	22·41	4·68	21·24	83	106
20–24	395·5	1,295	68	3·27	17·19	3·62	15·31	90	112
25–29	687·5	2,417	100	3·52	14·55	3·48	14·41	101	101
30–34	817·0	3,042	131	3·72	16·03	3·54	14·70	105	109
35–39	868·0	2,990	141	3·44	16·24	3·94	15·67	87	104
40–44	824·0	3,983	141	4·83	17·11	4·46	15·93	108	107
45–49	776·5	3,651	133	4·70	17·13	5·15	17·85	91	96
50–54	602·5	4,265	136	7·08	22·57	6·09	20·31	116	111
55–59	409·0	3,518	125	8·60	30·56	7·44	22·72	116	135
60–64	255·0	2,371	69	9·30	27·06	10·25	26·24	91	103
65–69	97·5	1,513	37	15·52	37·95	16·01	33·35	97	114
All Ages—									
Crude	6,201·0	30,860	1,186	4·98	19·13	5·36	18·35	101	109
Standardised				5·39	19·95	5·36	18·35		

* Age last birthday at beginning of year of exposure.
† In days per person-year of exposure.
‡ In claims per 100 person-years of exposure.

TABLE XIII.—*Disablement* (*after first* 26 *weeks*) *amongst Stereotypers and Electrotypers compared with that experienced by All Printers for the years* 1921–25.

Age Group.*	Person-years of exposure.	Total duration of disablement in days.	Number of disablement claims.	Stereotypers and Electrotypers.		All Printers.		Stereotypers and Electrotypers' rates as percentage of All Printers' rates.	
				Day rate.†	Claim rate.‡	Day rate †	Claim rate.‡	Day rate	Claim rate.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
16–19	265·5	—	—	—	—	·92	·77	—	—
20–24 .. .	392·5	—	—	—	—	1·50	·99	—	—
25–29 . .	681·5	273	4	·40	·59	1·87	1·00	21	59
30–34 ..	812·0	907	5	1·12	·62	2·33	1·17	48	53
35–39 ..	865·5	1,411	7	1·63	·81	2·26	1·27	72	64
40–44 . .	819·5	1,974	17	2·41	2·07	3·07	1·65	79	125
45–49 ..	773·0	2,914	18	3·77	2·33	3·88	2·02	97	115
50–54 .. .	602·5	2,836	18	4·71	2·99	4·82	2·67	98	112
55–59 . ..	409·0	2,502	14	6·12	3·42	7·33	3·60	83	95
60–64	254·0	3,995	36	15·73	14·17	17·50	8·00	90	177
65–69	97·5	2,830	11	29·03	11·28	38·75	16·46	75	69
All Ages—									
Crude ..	5,972·5	19,642	130	3·29	2·18	5·18	2·56	79	102
Standardised				4·08	2·62	5·18	2·56		

* Age last birthday at beginning of year of exposure.
† In days per person-year of exposure.
‡ In claims per 100 person-years of exposure.

TABLE XIV.—*Sickness (first 26 weeks) amongst Bookbinders and Machine Rulers compared with that experienced by All Printers for the years* 1921–25.

Age Group.*	Person-years of exposure.	Total duration of sickness in days.	Number of sickness claims	Bookbinders and Machine Rulers.		All Printers		Bookbinders' and Machine Rulers' rates as percentage of all Printers' rates.	
				Day rate.†	Claim rate ‡	Day rate.†	Claim rate ‡	Day rate.	Claim rate.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
16–19 . .	1,062·0	4,708	211	4·43	19·87	4·68	21·24	95	94
20–24	1,213·0	4,307	152	3·55	12·53	3·62	15·31	98	82
25–29 . . .	1,627·0	4,676	185	2·87	11·37	3·48	14·41	82	79
30–34 . .	2,260·0	6,279	275	2·78	12·17	3·54	14·70	79	83
35–39 . . .	1,990·0	7,090	237	3·56	11·91	3·94	15·67	90	76
40–44 .	1,782·0	6,191	209	3·47	11·73	4·46	15·93	78	74
45–49 . .	1,869·5	7,494	248	4·01	13·27	5·15	17·85	78	74
50–54 . .	1,503·0	8,180	231	5·44	15·37	6·09	20·31	89	76
55–59 . .	1,194·0	8,208	246	6·87	20·60	7·44	22·72	92	91
60–64 . . .	841·0	8,688	189	10·33	22·47	10·25	26·24	101	86
65–69 . . .	551·0	7,513	145	13·64	26·32	16·01	33·35	85	79
All Ages—									
Crude . .	15,892·5	73,334	2,328	4·61	14·65	5·36	18·35	87	80
Standardised				4·68	14·75	5·36	18·35		

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure.

In claims per 100 person-years of exposure.

TABLE XV—*Disablement (after first* 26 *weeks) amongst Bookbinders and Machine Rulers compared with that experienced by All Printers for the years* 1921–25

Age Group.* (1)	Person-years of exposure (2)	Total duration of disablement in days (3)	Number of disablement claims (4)	Bookbinders and Machine Rulers. Day rate.† (5)	Bookbinders and Machine Rulers. Claim rate.‡ (6)	All Printers. Day rate.† (7)	All Printers. Claim rate ‡ (8)	Bookbinders' and Machine Rulers' rates as percentage of all Printers' rates Day rate (9)	Bookbinders' and Machine Rulers' rates as percentage of all Printers' rates Claim rate. (10)
16–19 ..	623·5	340	7	·55	1·12	92	·77	60	145
20–24 .	1,204·5	2,064	12	1·71	1·00	1·50	·99	114	101
25–29	1,621·0	4,826	23	2·98	1·42	1·87	1·00	159	142
30–34 .	2,240·5	4,887	29	2·18	1·29	2·33	1·17	94	110
35–39 . .	1,979·5	2,873	22	1·45	1·11	2·26	1·27	64	87
40–44 .. .	1,775·5	11,824	53	6·66	2·99	3·07	1·65	217	181
45–49 .	1,862·0	10,887	44	5·85	2·36	3·88	2·02	150	117
50–54 ..	1,495·0	7,596	37	5·08	2·47	4·82	2·67	105	93
55–59 . .	1,188·5	8,063	46	6·78	3·87	7·33	3·60	92	108
60–64 .	840·5	20,112	84	23·93	9·99	17·50	8·00	137	125
65–69 .	548·5	13,789	61	25·14	11·12	38·75	16·46	65	68
All Ages— Crude ..	15,379·0	87,261	418	5·67	2·72	5·18	2·56	112	109
Standardised				5·82	2·78	5·18	2·56		

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* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure

‡ In claims per 100 person-years of exposure.

TABLE XVI.—*Sickness (first* 26 *weeks) amongst Printers' Warehousemen and Cutters compared with that experienced by All Printers for* 1921–25.

Age Group.* (1)	Person-years of exposure. (2)	Total duration of sickness in days. (3)	Number of sickness claims. (4)	Printers' Warehousemen and Cutters.		All Printers.		Printers' Warehousemen and Cutters' rates as percentage of All Printers' rates.	
				Day rate † (5)	Claim rate.‡ (6)	Day rate.† (7)	Claim rate.‡ (8)	Day rate (9)	Claim rate. (10)
16–19	369·5	1,369	75	3 71	20 30	4 68	21·24	79	96
20–24 . ..	514·5	1,300	73	2·53	14·19	3 62	15·31	70	93
25–29 ..	699·5	3,413	106	4 88	15·15	3 48	14 41	140	105
30–34 . .	1,088·5	4,443	169	4 08	15 53	3 54	14·70	115	106
35–39 .	1,305·5	8,686	252	6 65	19 30	3·94	15·67	169	123
40–44 ..	1,295·0	6,924	230	5 35	17·76	4·46	15·93	120	111
45–49	1,411·0	8,596	285	6 09	20·20	5·15	17·85	118	113
50–54 .. .	1,222·0	8,629	264	7·06	21·60	6·09	20·31	116	106
55·59 ..	829·5	6,330	171	7·63	20·61	7·44	22·72	103	91
60–64 . ..	495·0	6,382	163	12 89	32 93	10·25	26·24	126	125
65–69 . ..	237·5	3,633	83	15·30	34·95	16·01	33·35	96	105
All Ages—									
Crude ..	9,467·5	59,705	1,871	6·31	19·76	5 36	18·35	117	108
Standardised				6 25	19 76	5 36	18·35		

* Age last birthday at beginning of year of exposure.
† In days per person-year of exposure.
‡ In claims per 100 person-years of exposure.

TABLE XVII.—*Disablement (after first 26 weeks) amongst Printers' Warehousemen and Cutters compared with that experienced by All Printers for* 1921–25.

Age Group.* (1)	Person-years of exposure (2)	Total duration of disablement in days. (3)	Number of disablement claims (4)	Printers' Warehousemen and Cutters.		All Printers		Printers' Warehousemen and Cutters' rates as percentage of All Printers' rates.	
				Day rate † (5)	Claim rate ‡ (6)	Day rate † (7)	Claim rate ‡ (8)	Day rate. (9)	Claim rate. (10
16–19	208·5	31	1	·15	·48	·92	·77	16	62
20–24 . ..	506·0	497	2	·98	·40	1·50	·99	65	40
25–29	685·0	2,805	16	4·09	2 34	1 87	1 00	219	234
30–34 . .	1,066 0	2,023	14	1·90	1·31	2 33	1·17	82	112
35–39 . ..	1,285·0	7,284	39	5·67	3·04	2·26	1·27	251	239
40–44 ..	1,272·5	6,081	27	4·78	2·12	3·07	1 65	158	128
45–49 . ..	1,397·0	6,077	28	4·35	2·00	3·88	2·02	112	99
50–54 . .	1,211·0	12,166	62	10·05	5 12	4 82	2·67	209	192
55–59 . ..	827·0	1,912	14	2·31	1·69	7 33	3·60	31	47
60–64	491·5	4,426	25	9 01	5 09	17·50	8·00	51	63
65–69	237·5	3,402	31	14·32	13 05	38 75	16·46	37	79
All Ages—									
Crude ..	9,187·0	46,704	259	5·08	2·82	5·18	2·56	96	109
Standardised				4·96	2 79	5 18	2·56		

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* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure.

‡ In claims per 100 person-years of exposure.

TABLE XVIII.—*Sickness (first 26 weeks) amongst Lithographic Machine Printers compared with that experienced by All Printers for* 1921–25.

Age Group.* (1)	Person-years of exposure. (2)	Total duration of sickness in days (3)	Number of sickness claims. (4)	Lithographic Machine Printers. Day rate † (5)	Lithographic Machine Printers. Claim rate.‡ (6)	All Printers Day rate † (7)	All Printers Claim rate ‡ (8)	Lithographic Machine Printers' rates as percentage of All Printers' rates. Day rate. (9)	Lithographic Machine Printers' rates as percentage of All Printers' rates. Claim rate. (10)
16–19	780·0	3,221	159	4·13	20·38	4·68	21·24	88	96
20–24	953·5	4,483	175	4·70	18·35	3·62	15·31	130	120
25–29	1,464·0	4,572	221	3·12	15·10	3·48	14·41	90	105
30–34	1,956·5	7,544	358	3·86	18·30	3·54	14·70	109	124
35–39	2,005·5	7,702	336	3·84	16·75	3·94	15·67	97	107
40–44	1,992·0	8,935	331	4·49	16·62	4·46	15·93	101	104
45–49	2,126·5	10,153	397	4·77	18·67	5·15	17·85	93	105
50–54	1,894·0	12,621	446	6·66	23·55	6·09	20·31	109	116
55–59	1,389·0	9,225	305	6·64	21·96	7·44	22·72	89	97
60–64	835·0	8,700	229	10·42	27·43	10·25	26·24	102	105
65–69	383·5	6,340	158	16·53	41·20	16·01	33·35	103	124
All Ages—									
Crude	15,779·5	83,496	3,115	5·29	19·74	5·36	18·35	100	109
Standardised				5·36	19·91	5·36	18·35		

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure

‡ In claims per 100 person-years of exposure.

TABLE XIX.—*Disablement (after first* 26 *weeks) amongst Lithographic Machine Printers compared with that experienced by All Printers for* 1921–25.

Age Group.* (1)	Person-years of exposure. (2)	Total duration of disablement in days. (3)	Number of disablement claims. (4)	Lithographic Machine Printers. Day rate.† (5)	Lithographic Machine Printers. Claim rate.‡ (6)	All Printers. Day rate.† (7)	All Printers. Claim rate.‡ (8)	Lithographic Machine Printers' rates as percentage of All Printers' rates Day rate. (9)	Lithographic Machine Printers' rates as percentage of All Printers' rates Claim rate. (10)
16–19	434·5	164	3	·38	·69	·92	·77	41	90
20–24 ..	943·5	3,419	19	3·62	2·01	1·50	·99	241	203
25–29 ..	1,449·5	1,633	9	1·13	·62	1·87	1·00	60	62
30–34 . ..	1,940·0	5,091	24	2·62	1·24	2·33	1·17	112	106
35–39 ..	1,982·5	2,551	18	1·29	·91	2·26	1·27	57	72
40–44	1,979·0	4,037	26	2·04	1·31	3·07	1·65	66	79
45–49 . ..	2,103·5	7,174	38	3·41	1·81	3·88	2·02	88	89
50–54 . ..	1,872·0	8,546	47	4·57	2·51	4·82	2·67	95	94
55–59 .	1,381·5	14,482	64	10·48	4·63	7·33	3·60	142	129
60–64	830·5	16,116	65	19·41	7·83	17·50	8·00	111	98
65–69 . ..	380·5	11,852	51	31·15	13·40	38·75	16·46	80	81
All Ages—									
Crude ..	15,297·0	75,065	364	4·91	2·38	5·18	2·56	98	96
Standardised				5·07	2·45	5·18	2·56		

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* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure.

‡ In claims per 100 person-years of exposure.

TABLE XX.—*Number of Days of Sickness (first 26 weeks) suffered per Claim made (within the Calendar Year).*

Age Group.	All Printers.	Compositors.	Machine Printers.	Stereotypers and Electrotypers	Bookbinders and Rulers.	Warehousemen and Cutters.	Lithographic Printers.
16–19 ..	22·0	23·6	20·9	17·3	22·3	18·3	20·3
20–24 ..	23·6	22·9	24·3	19·0	28·3	17·8	25·6
25–29 ..	24·1	22·8	25·5	24·2	25·3	32·2	20·7
30–34 ..	24·1	23·9	26·3	23·2	22·8	26·3	21·1
35–39 ..	25·1	22·0	26·1	21·2	29·9	34·5	22·9
40–44 ..	28·0	24·6	31·1	28·2	29·6	30·1	27·0
45–49 ..	28·8	27·9	31·1	27·5	30·2	30·2	25·6
50–54 ..	30·0	28·2	31·4	31·4	35·4	32·7	28·3
55–59 ..	32·7	32·1	34·9	28·1	33·4	37·0	30·2
60–64 ..	39·1	39·2	36·2	34·4	46·0	39·2	38·0
65–69 ..	48·0	50·2	47·2	40·9	51·8	43·8	40·1
All Ages—Crude ..	29·2	28·9	29·8	26·0	31·5	31·9	26·8

TABLE XXI.—*Number of Days of Disablement (after first 26 weeks) suffered per Claim made (within the Calendar Year).*

Age Group.	All Printers.	Compositors.	Machine Printers.	Stereotyers and Electrotypers.	Bookbinders and Rulers.	Warehousemen and Cutters.	Lithographic Printers.
16–19 . .	120·5	159·9	120·8	—	48·6	31·0	54·7
20–24 . .	151·3	140·5	119·1	—	172·0	248·5	179·9
25–29 . .	187·5	211·1	175·0	68·3	209·8	175·3	181·4
30–34 . .	199·9	244·5	167·4	181·4	168·5	144·5	212·1
35–39 . .	178·5	197·4	178·8	201·6	130·6	186·8	141·7
40–44 . .	186·4	197·3	160·7	116·1	223·1	225·2	155·3
45–49 . .	191·8	198·3	158·0	161·9	247·4	217·0	188·8
50–54 . .	180·6	176·7	172·8	157·6	205·3	196·2	181 8
55–59 .	203·6	235·2	149·1	178·7	175·3	136·6	226·3
60–64 . .	218·8	229·9	194·0	111·0	239·4	177·0	247·9
65–69 . .	235·4	247·1	227·6	257·3	226·0	109·7	232·4
All Ages . .	202·3	222·7	172·1	151·1	208·8	180·3	206·2

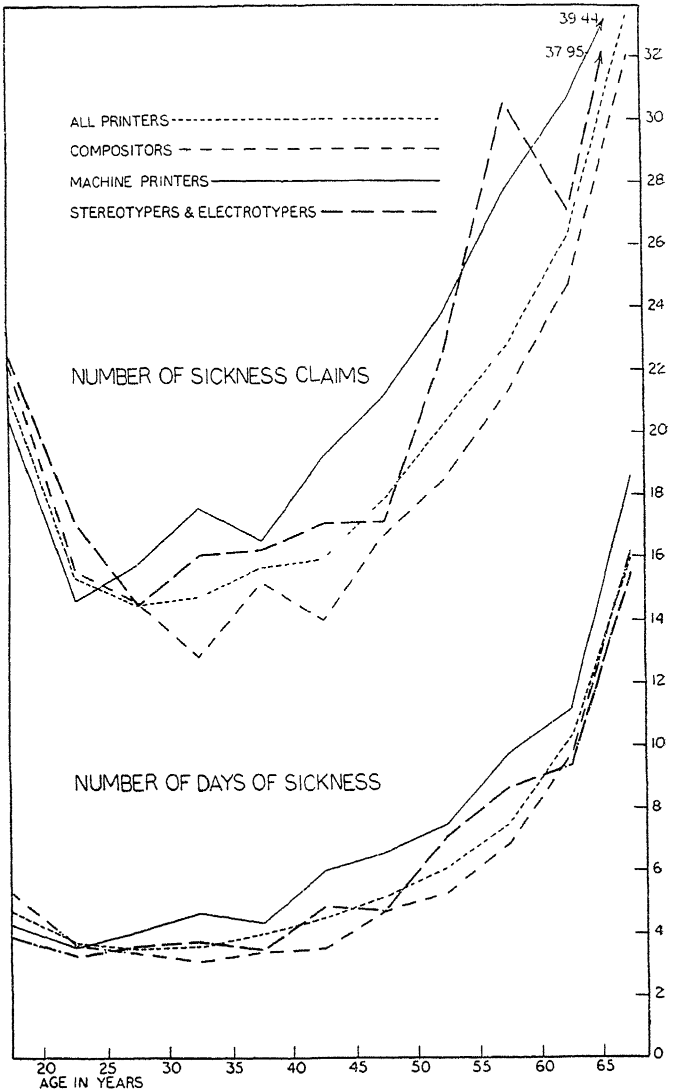

Fig. 1.—Number of days of sickness per person-year of exposure and number of sickness claims per 100 person-years of exposure for all printers, compositors, machine printers, stereotypers and electrotypers.

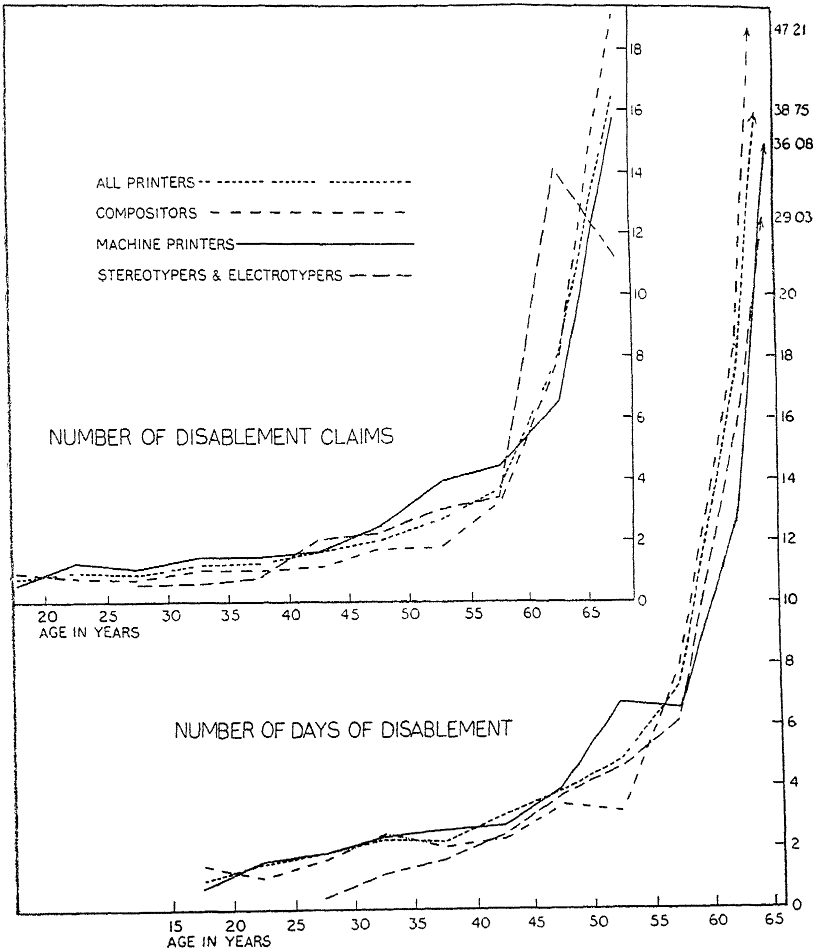

Fig. 2.—Number of days of disablement per person-year of exposure and number of disablement claims per 100 person-years of exposure for all printers, compositors, machine printers, stereotypers and electrotypers.

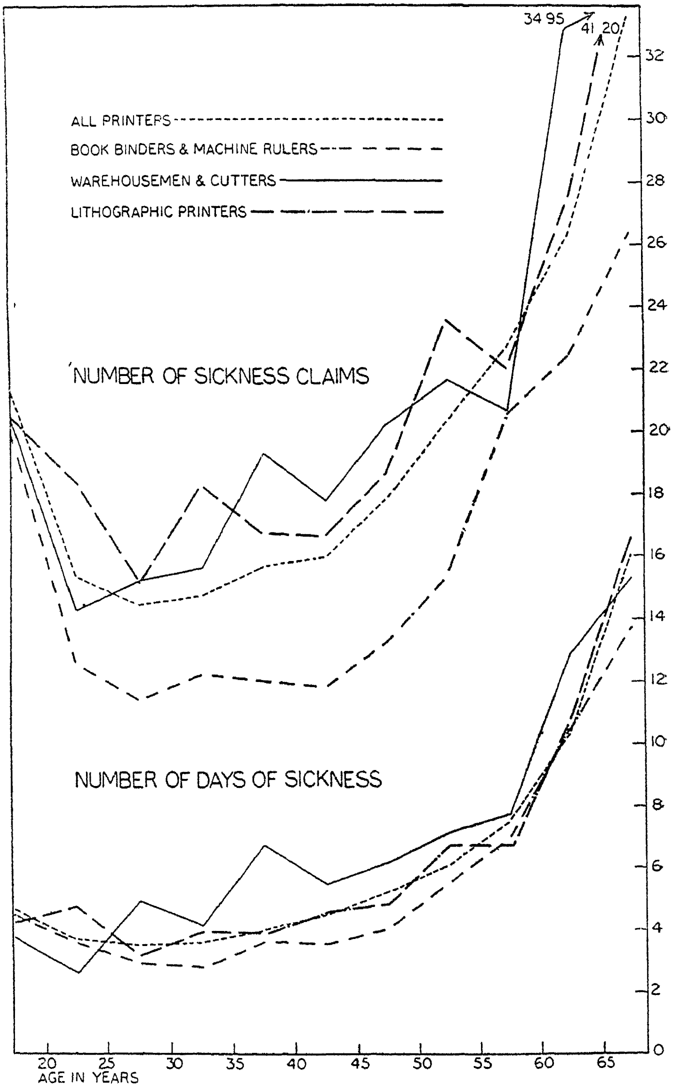

Fig. 3.—Number of days of sickness per person-year of exposure and number of sickness claims per 100 person-years of exposure for all printers, bookbinders and machine rulers, warehousemen and cutters, lithographic printers.

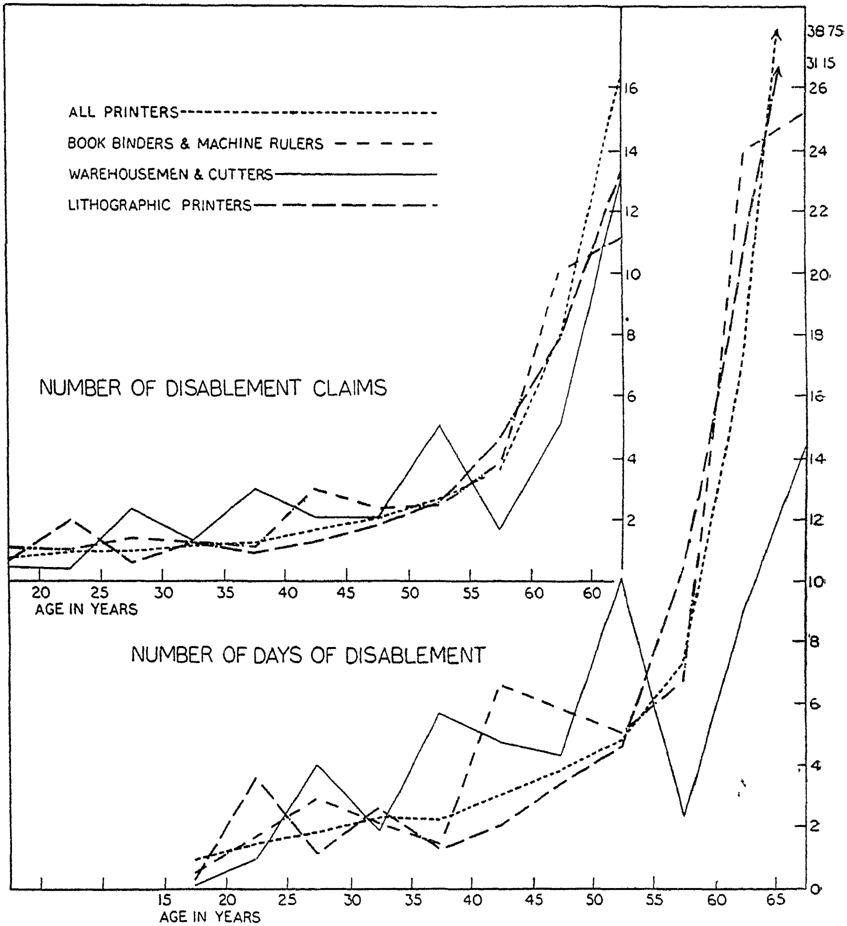

Fig. 4 —Number of days of disablement per person-year of exposure and number of disablement claims per 100 person-years of exposure for all printers, bookbinders and machine rulers, warehousemen and cutters, lithographic printers.

There is evidence of random fluctuations (more evident in the percentages since both the compositors' rate and the other occupational rate may fluctuate together at random and in opposite directions) For this reason the differences are not shown diagrammatically The indication is that compositors again have an excess of incapacity in the first age-group, 16–19, and that also they are at some disadvantage in the last few years of insured life, from 65–69, in which years they have longer periods of incapacity and more claims The machine printers from age 25–59 are still adversely placed, having more days of sickness per person-year, and making considerably more claims than compositors, though the length of their claims is on the average below that for compositors The same is true of warehousemen at ages 25–54, while these workers have in several age groups longer as well as more claims. Bookbinders who in the sickness tables showed to advantage, even over compositors, now show appreciably more claims, and on the whole, more days of disablement. Stereotypers have a more favourable experience to begin with than compositors, but in middle age show a larger number of claims of relatively short duration. Lithographic machine printers give erratic percentages tending on the whole to make more claims than, but to lose only about the same amount of time through disablement as, compositors.

The reply that is given by these comparisons may now be conveniently summarised

Compositors start insured life with a very unfavourable morbidity experience , their position improves in the next age group, 20–24, and at 25–64 they suffer considerably less than other classes of printers with the exception of bookbinders. These latter workers show very low sickness rates, except that their duration per claim is high, and yet compared with compositors or with all printers, they show an excess of disablement. Machine printers and warehousemen produce an unfavourable impression in these comparisons. For many years of their working life they experience considerably higher sickness rates than do others in the printing trade. They do not show the initial very high rate of the compositors, and in late life, again, they begin to lose their position of disadvantage, but at roughly, ages 25–59 for machine workers and at 25–54 for warehousemen the rates are definitely in excess of those shown by compositors and all printers. Stereotypers and electrotypers and lithographic machine printers make more claims than all printers and more than compositors but their claims are of shorter duration.

Going a step further, it will be of some interest to see if the differences shown between these occupational groups are stable from year to year. The sickness and disablement experiences have been analysed for each calendar year separately, 1921–25, and the rates are set out in Tables XXVI and XXVII, in absolute figures and expressed as percentages of the rates for all printers.

TABLE XXII.—*Sickness (first 26 weeks) amongst All Printers and in each Occupational Group for the years* 1921–25.

Age Group.*	All Printers.		Compositors.		Machine Printers.		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
(1)	Day rate † (2)	Claim rate.‡ (3)	Day rate.† (4)	Claim rate.‡ (5)	Day rate.† (6)	Claim rate.‡ (7)	Day rate.† (8)	Claim rate.‡ (9)	Day rate † (10)	Claim rate ‡ (11)	Day rate † (12)	Claim rate ‡ (13)	Day rate † (14)	Claim rate ‡ (15)
16–19	4·68	21·24	5 23	22·15	4·27	20·38	3 87	22·41	4·43	19 87	3 71	20 30	4 13	20·38
20–24 . ..	3·62	15 31	3·56	15·56	3·56	14·62	3·27	17 19	3 55	12 53	2·53	14·19	4·70	18·35
25–29	3·48	14 41	3·32	14 56	4 04	15·80	3 52	14 55	2 87	11 37	4 88	15·15	3·12	15·10
30–34	3·54	14 70	3·05	12 78	4 63	17·60	3·72	16 03	2 78	12 17	4·08	15·53	3·86	18·30
35–39	3·94	15·67	3·34	15·16	4·32	16·54	3·44	16·24	3 56	11 91	6·65	19 30	3·84	16 75
40–44 .. .	4·46	15·93	3·44	13·97	5·97	19·21	4·83	17 11	3 47	11 73	5 35	17 76	4·49	16·62
45–49	5·15	17·85	4·66	16·67	6 56	21·10	4·70	17 13	4·01	13 27	6 09	20·20	4·77	18·67
50–54 .. .	6·09	20·31	5·21	18·50	7·50	23·90	7 08	22·57	5 44	15·37	7·06	21 60	6 66	23 55
55–59	7·44	22·72	6·81	21·22	9·71	27·78	8·60	30·56	6 87	20·60	7·63	20·61	6·64	21·96
60–64	10·25	26·24	9·65	24·63	11·12	30·73	9·30	27·06	10 33	22 47	12·89	32 93	10·42	27·43
65–69	16·01	33·35	16·08	32·04	18·61	39·44	15·52	37·95	13·64	26 32	15 30	34 95	16 53	41 20
All Ages—														
Crude ..	5·36	18·35	5·11	17·68	6·05	20·27	4·98	19·13	4·61	14·65	6·31	19·76	5·29	19·74
Standardised	5·36	18·35	4·86	17·26	6·42	20·95	5·39	19·95	4 68	14 75	6·25	19·76	5 36	19 91

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure

‡ In claims per 100 person-years of exposure.

TABLE XXIII.—*The Sickness Rates (first 26 weeks) for each Occupational Group expressed as percentages of the corresponding Rates for Compositors.* 1921–25. (*Compositors* = 100 *at each age.*)

Age Group.	Machine Printers.		Stereotypers and Electrotypers.		Bookbinders and Rulers.		Warehousemen and Cutters.		Lithographic Printers.	
	Day rate.	Claim rate.	Day rate.	Claim rate	Day rate.	Claim rate.	Day rate.	Claim rate	Day rate.	Claim rate.
16–19	82	92	74	101	85	90	71	92	79	92
20–24	100	94	92	110	100	81	71	91	132	118
25–29	122	109	106	100	86	78	147	104	94	104
30–34	152	138	122	125	91	95	134	122	127	143
35–39	129	109	103	107	107	79	199	127	115	110
40–44	174	138	140	122	101	84	156	127	131	119
45–49	141	127	101	103	86	80	131	121	102	112
50–54	144	129	136	122	104	83	136	117	128	127
55–59	143	131	126	144	101	97	112	97	98	103
60–64	115	125	96	110	107	91	134	134	108	111
65–69	116	123	97	118	85	82	95	109	103	129
All Ages (using standardised rates).	132	121	111	116	96	85	129	114	110	115

TABLE XXIV —*Disablement (after first 26 weeks) amongst All Printers and in each Occupational Group for the years* 1921–25

Age Group.*	All Printers.		Compositors		Machine Printers		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
	Day rate.†	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate.†	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate.†	Claim rate.‡
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
16–19	·92	·77	1·47	92	·67	·55	—	—	·55	1 12	·15	48	·38	69
20–24	1·50	99	1·04	74	1 53	1·29	—	—	1 71	1 00	98	40	3 62	2 01
25–29 ..	1·87	1·00	1·61	77	1·81	1·03	·40	·59	2 98	1 42	4 09	2 34	1·13	·62
30–34	2·33	1·17	2·51	1·03	2·38	1·42	1·12	·62	2 18	1·29	1 90	1 31	2·62	1·24
35–39	2·26	1·27	2·03	1 03	2 57	1 43	1 63	·81	1 45	1 11	5·67	3 04	1 29	91
40–44	3·07	1·65	2·30	1·17	2·76	1·72	2 41	2·07	6·66	2·99	4·78	2 12	2·04	1·31
45–49 .. .	3 88	2 02	3·44	1·73	3·93	2·49	3·77	2·33	5·85	2·36	4·35	2·00	3·41	1·81
50–54	4 82	2·67	3 16	1 79	6 75	3 91	4·71	2 99	5 08	2 47	10·05	5 12	4 57	2·51
55–59	7·33	3·60	7 76	3 30	6 58	4·42	6 12	3 42	6 78	3 87	2 31	1 69	10 48	4 63
60–64	17 50	8 00	18·28	7 95	12 62	6·51	15 73	14 17	23 93	9 99	9 01	5 09	19·41	7 83
65–69	38 75	16 46	47 21	19·11	36 08	15·85	29·03	11 28	25 14	11 12	14 32	13·05	31 15	13 40
All Ages—														
Crude ..	5·18	2·56	5 82	2 61	4 27	2 48	3 29	2 18	5 67	2 72	5 08	2 82	4 91	2 38
Standardised	5 18	2·56	5·12	2 33	4 99	2·82	4 08	2 62	5 82	2 78	4 96	2·79	5 07	2 45

* Age last birthday at beginning of year of exposure
† In days per person-year of exposure
‡ In claims per 100 person-years of exposure.

TABLE XXV.—*The Disablement Rates (after first 26 weeks) for each Occupational Group expressed as percentages of the corresponding Rates for Compositors.* 1921–25. (*Compositors* = 100 *at each age.*)

Age Group.	Machine Printers.		Stereotypers and Electrotypers.		Bookbinders and Rulers.		Warehousemen and Cutters.		Lithographic Printers.	
	Day rate	Claim rate.	Day rate.	Claim rate	Day rate.	Claim rate	Day rate.	Claim rate	Day rate.	Claim rate.
16–19	46	60	—	—	37	122	10	52	26	75
20–24	147	174	—	—	164	135	94	54	348	272
25–29	112	134	25	77	185	184	254	304	70	81
30–34 . .	95	138	45	60	87	125	76	127	104	120
35–39	127	139	80	79	71	108	279	295	64	88
40–44	120	147	105	177	290	256	208	181	89	112
45–49	114	144	110	135	170	136	126	116	99	105
50–54	214	218	149	167	161	138	318	286	145	140
55–59	85	134	79	104	87	117	30	51	135	140
60–64	69	82	86	178	131	126	49	64	106	98
65–69	76	83	61	59	53	58	30	68	66	70
All Ages (using standardised rates).	97	121	80	112	114	119	97	120	99	105

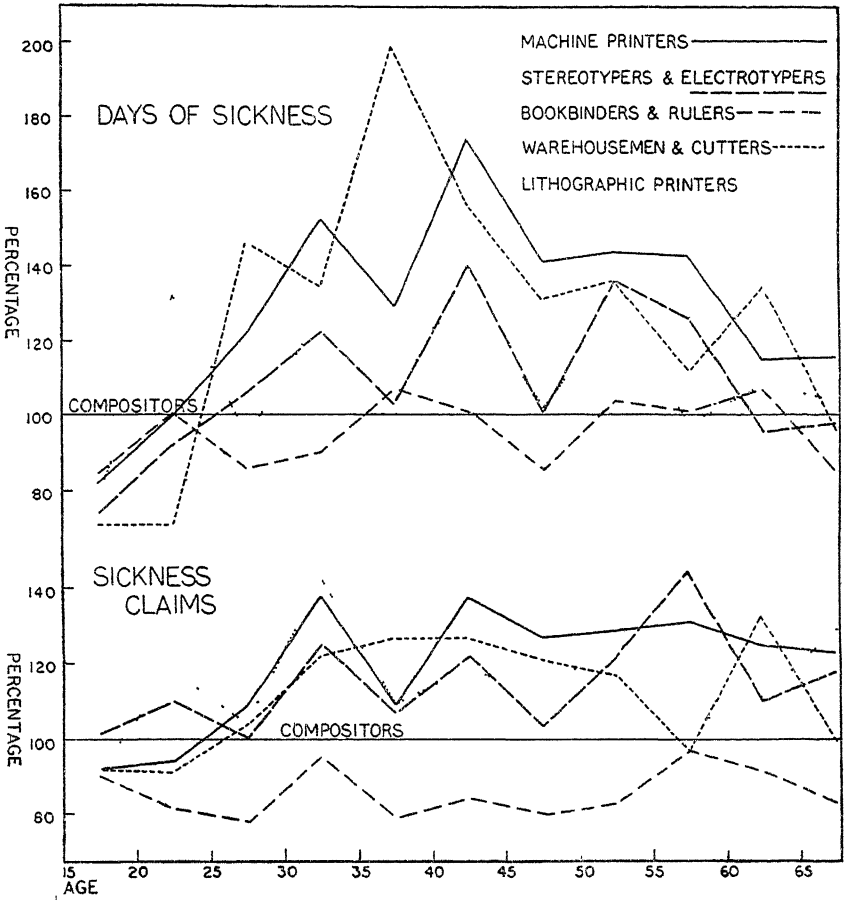

Fig. 5 —The sickness day rate and claim rate (first 26 weeks) for each occupational group expressed as percentages of the corresponding rates for compositors.

The compositors' and the machine printers' rates for sickness relative to those for all printers, it will be observed, are extremely consistent. The former class in every year have slightly lower rates than all printers, the latter have definitely higher rates. In disablement the compositors still hold their slight advantage (except in 1921), but the machinemen have improved their position as to amount of time lost, though their claims are still in excess. Similarly, bookbinders have lower rates and warehousemen have higher rates for sickness in each year than all printers. In disablement the bookbinders lose their advantage and make more claims and have more days of incapacity than all printers. Warehousemen still, on the whole, have an excess of claims, but fewer days per person-year The percentages again are very reasonably consistent from year to year. For stereotypers and electrotypers and for lithographic machine printers the relative rates are not quite so consistent. For 1921–23 the stereotypers have higher rates while for 1924–25 their sickness compares favourably with all printers. For lithographic printers the converse is seen , from 1921–23 they do not differ materially from all printers, while from 1924–25 they have somewhat of an excess of short sickness claims. In disablement the stereotypers, on the whole, show to advantage, while the lithographic printers reveal no really material differences between themselves and all printers.

This analysis of the sickness and disablement year by year thus confirms the main conclusions already reached from consideration of the 1921–25 rates, of which a summary has just been given.

Before turning to causes of incapacity one final comparison will be made between the several occupational groups—the question being what proportion of the total population in any one group suffered from illness during the period of survey and how many of them made more claims than one. The figures in answer are given in Tables XXVIII and XXIX.

Looking at those for all printers in the former table it is seen, as would be expected in view of the results already reached, that there is a high percentage of persons ill in the first years of occupied life, 48·4 per cent. of all persons exposed suffering from incapacity during the five years. After that, except for a dip at age 30–39, the percentage remains quite constant at a level of 43 to 44 for some 35 years of life. There is a definite rise towards the end of insured life and in the final group, 60–69, nearly 60 per cent. of the population are incapacitated at one time or another during the five years' survey. The figures for the occupational groups confirm by another test the results already reached. Compositors begin with a high percentage, 52·1 suffering illness, then gradually improve and until the final age group have a less proportion falling ill than all printers. For machine printers it is the reverse ; they begin favourably but then deteriorate and by age 30–39 show a distinct excess of sick persons which continues for the rest of their insurance history. Warehousemen and cutters begin

TABLE XXVI.—*Standardised Rates for all ages for All Printers and for each Occupational Group of Printers for each year* 1921 to 1925. *Sickness (first* 26 *weeks).*

Year.	All Printers.		Compositors.		Machine Printers.		Stereotypers and Electrotypers.		Bookbinders and Rulers.		Warehousemen and Cutters		Lithographic Printers.	
	Day rate.*	Claim rate.†	Day rate.*	Claim rate.†	Day rate *	Claim rate.†	Day rate.*	Claim rate.†	Day rate.*	Claim rate †	Day rate *	Claim rate †	Day rate *	Claim rate.†
1921	4·88	15·71	4·44	14·92	5·49	17·29	5·91	17·60	5·05	13·99	5·43	17·27	4·64	16·25
1922	5·11	17·44	4·47	16·60	6·53	20·46	5·28	19·21	4·82	13·85	5·83	18·38	4·89	18·05
1923	5·03	16·55	4·61	15·79	6·02	19·10	5·45	19·97	4·39	12·38	6·02	17·73	4·87	17·61
1924	5·77	20·05	5·51	19·22	6·83	22·77	5·09	19·98	4·26	15·07	6·31	21·21	5·85	22·27
1925	5·96	21·92	5·31	19·90	7·08	24·84	5·29	22·40	4·88	18·50	7·35	23·73	6·54	25·40

The Standardised Rates given above for each Occupational Group expressed as a percentage of the corresponding Rate for All Printers

1921	100	100	91	95	112	110	121	112	103	89	111	110	95	103
1922	100	100	87	95	128	117	103	110	94	79	114	105	96	103
1923	100	100	92	95	120	115	108	121	87	75	120	107	97	106
1924	100	100	95	96	118	114	88	100	74	75	109	106	101	111
1925	100	100	89	91	119	113	89	102	82	84	123	108	110	116

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* In days per person-year of exposure.

† In claims per 100 person-years of exposure.

TABLE XXVII.—*Standardised rates for all ages for All Printers and for each Occupational Group of Printers for each year* 1921 to 1925. *Disablement (after first 26 weeks).*

Year.	All Printers.		Compositors.		Machine Printers		Stereotypers and Electrotypers		Bookbinders and Rulers.		Warehousemen and Cutters		Lithographic Printers	
	Day rate.*	Claim rate.†	Day rate *	Claim rate†.	Day rate.*	Claim rate †	Day rate *	Claim rate †	Day rate.*	Claim rate †	Day rate *	Claim rate †	Day rate *	Claim rate †
1921	4·26	2·16	4·71	2·13	3·87	2·23	3·18	1·70	4·04	2·38	3·62	2·18	4·20	2·23
1922	4·76	2·36	4·76	2·17	4·27	2·44	4·65	2·73	5·39	2·73	4·23	2·87	4·90	1·90
1923	5·23	2·56	4·98	2·37	4·89	2·64	4·34	2·66	6·76	2·99	4·96	2·91	4·96	2·25
1924 .. .	5·64	2·77	5·34	2·46	5·70	3·09	4·11	2·58	6·79	3·11	5·63	2·60	5·33	2·80
1925	5·90	2·92	5·76	2·50	5·73	3·50	3·79	3·12	6·47	2·75	6·12	3·27	5·94	3·07

The Standardised rates given above for each Occupational Group expressed as a percentage of the corresponding rate for All Printers

1921	100	100	111	99	91	103	75	79	95	110	85	101	99	103
1922	100	100	100	92	90	103	98	116	113	116	89	122	103	81
1923	100	100	95	93	93	103	83	104	129	117	95	114	95	88
1924 . ..	100	100	95	89	101	112	73	93	120	112	100	94	95	101
1925	100	100	98	86	97	120	64	107	110	94	104	112	101	105

* In days per person-year of exposure.
† In claims per 100 person-years of exposure.

TABLE XXVIII.—*The Number of Persons in each Occupational Group who suffered from illness (Sickness or Disablement) during* 1921–25 *expressed as a percentage of the Total Population in that Group.**

Age Group.	All Printers.	Compositors.	Machine Printers.	Stereotypers and Electrotypers.	Bookbinders and Rulers	Warehousemen and Cutters	Lithographic Printers
16–24 . .	48·4	52·1	44·3	50 0	39·3	29·4	64·2
20–29 . .	44·0	45·1	45·8	40 3	37·1	38·9	50·3
25–34 . .	44·2	45·5	44·1	50·0	39·2	48·5	42·5
30–39 . .	39·9	38·9	42·1	34·3	32·4	41·9	47·5
35–44 . .	43·1	41·2	46 3	49·6	34·7	46·0	44·4
40–49 . .	42·8	41·2	47·3	32·1	37·5	46·0	45·3
45–54 . .	44·4	43·0	47·8	33·3	41·9	46·5	47·5
50–59 . .	47·3	46·2	51·8	53·2	40·2	43·0	51·1
55–64 . .	50·3	49·5	54·1	52·3	45·5	52·7	50·0
60–69 . .	59·5	60·2	61·2	41·7	51·2	64·2	64·7

* This table applies only to persons exposed for the *whole* of the 5 years, i e no entries or exits are included (hence it stops at age 64, since any person over that age at 1.1.21 automatically ceased to be insured and became an exit before 31.12 25) Since the age grouping was made on the basis of age at 1 1.21 each group must overlap, for some persons aged 15–19 at 1 1.21 would be 20–24 before 31.12.25, and the 20–24 group would include persons aged 25–29 for part of the 5 years. The Table reads Of all printers of age 15–24, 48·4 per cent. suffered illness during 1921–25 ; of compositors in the same group 52·1 per cent. suffered illness, of machinemen 44·3 per cent. were ill and so on.

TABLE XXIX.—*Number of Persons in each Occupational Group exposed for the whole 5 years, who suffered from one or more periods of Sickness (Disablement cases included) during the 5 years, expressed as per cent. of the Total Number Sick in each Group* All Ages (Crude).*

Occupational Group.	Total Number who experienced sickness during the 5 years.	Percentage of total number sick who suffered from sickness once, or more than once. Number of times sick.						
		1	2	3	4	5	6	7 and more.
All Printers	9,793	56·6	23·8	10·2	4·9	2·0	1·2	1·3
Compositors	4,104	57·6	24·0	9·8	4·6	2·0	1·1	·8
Machine Printers	2,320	54·2	23·9	11·3	5·7	2·1	1·3	1·6
Stereotypers and Electrotypers	382	54·2	27·0	9·7	4·7	1·6	·3	2·5
Bookbinders and Rulers ..	982	62·8	22·2	8·7	3·6	1·4	·6	·7
Warehousemen and Cutters	727	57·1	22·6	9·4	5·2	2·3	1·5	1·9
Lithographic Printers ..	1,247	53·6	23·9	10·8	5·2	2·3	2·1	2·1

* The Table reads : Of all printers 9,793 suffered from sickness during 1921–25 ; of these 56·6 per cent were ill once, 23·8 per cent. were ill twice, 10·2 per cent. were ill three times, 4·9 per cent. were ill four times, etc., and thus for each occupational group.

still more favourably, only 29·4 per cent suffering from sickness in the first age group, yet from age 25–69 (excluding one age group, 50–59) they show a higher incidence than the total group. Bookbinders show a superiority throughout life (the sickness claims, of course, far outweigh those from disablement, so that their relatively unfavourable disablement experience is not here reflected). Stereotypers and electrotypers give fluctuating figures and no clear answer can be gained from them Lithographic printers begin with a strikingly high percentage falling sick—64·2 per cent (their sickness and disablement rates were abnormally high at age 20–24, as shown in Tables XXII and XXIII) and for most of their insured life a larger proportion of them suffer from illness than is found among the other groups of printers.

Table XXIX, dealing with the incidence of repeated claims, shows that amongst compositors of all ages there is a smaller proportion amongst the claimants making three or more claims to benefit during the five years than amongst all printers. With bookbinders the proportion making such multiple claims is still more in defect of those in the total group On the other hand, the claimants amongst machine printers, warehousemen, and lithographic printers, all show an undue proportion of persons who have repeated attacks of illness in the period of survey. The claimants amongst stereotypers have a high proportion making two claims, but on the whole do not include so many persons liable to multiple attacks of sickness.

It remains to see whether an analysis of the *causes* of sickness producing these different rates that have been found amongst the occupational groups will supply an explanation of the divergencies.

ANALYSIS OF THE MORBIDITY FOUND IN THE OCCUPATIONAL GROUPS OF PRINTERS ACCORDING TO CAUSE OF INCAPACITY.

For the purpose of comparing the nature of the morbidity suffered in the various occupational groups, 15 main cause groups were adopted These were as follows :

Table XXX —The Morbidity Cause Groups adopted.

1	*Influenza*	Influenza, post-influenzal debility, influenzal cold
2	*Phthisis*	Phthisis, haemoptysis, tuberculosis.
3	*Rheumatism* . .	Rheumatism, sciatica, lumbago, perichondritis, myositis, synovitis, bursitis, arthritis, fibrositis, myalgia, torticollis
4	*Diseases of the Respiratory System*	Bronchitis, pneumonia, asthma, pleurisy, cold, pleurodynia, coryza, catarrh, emphysema, congestion of the lungs
5	*Diseases of the Naso-pharyngeal and upper digestive tract*	Tonsillitis, sore throat, laryngitis, ulcerated throat, quinsy, pharyngitis, polypus, rhinitis, tracheitis, antrum, septic throat

6. *Diseases of the Circulatory System*	Anaemia, chlorosis, angina pectoris, arterial sclerosis, aneurysm, dropsy, mitral disease, phlebitis, varicose veins, tachycardia, purpura, morbis cordis, piles, haemorrhoids, ulcerated leg, endocarditis, pericarditis, myxoedema
7. *Diseases of the Digestive System*	Constipation, diarrhoea, dysentery, hernia, dyspepsia, indigestion, gastritis, gastric catarrh, gastric ulcer, colitis, gallstones, colic, peritonitis, appendicitis, enteritis
8 *Diseases of the Nervous System*	Thrombosis, embolism, insanity, neurasthenia, hysteria, neuritis, epilepsy, neuralgia, nervous debility, vertigo, myelitis, insomnia, chorea, faints, paralysis, tabes, cerebral haemorrhage.
9. *Diseases of the Skin*	Erythema, erysipelas, dermatitis, impetigo, urticaria, herpes zoster, abscess, adenitis, cellulitis, pyaemia, glands, boils, furunculosis, septic sores
10. *Diseases of the Urinary System*	Nephritis, Bright's disease, renal stricture, cystitis, calculus, haematuria, albuminuria.
11 *Diseases of the Reproductive System*	Orchitis, menorrhagia, epididymitis, dysmenorrhoea, salpingitis, endometritis, mastitis, climacteria, hydrocele.
12 *Other Causes*	Cancer, diabetes, debility, asthenia, otitis media, mastoid disease, conjunctivitis, glaucoma, myopia, ophthalmia, chicken pox, measles, scarlet fever, mumps, parotitis, diphtheria, pyrexia, chill, malaria, febricula, migraine, rheumatic fever, acute rheumatism, cyst, carbuncle, fistula, osteitis, necrosis, jaundice, dental trouble
13 *Accidents*	Accidents, burns, sprains *
14 *Gout*	Gout, podagra
15 *Not stated.*	

Where two causes were given or a change in diagnosis was made during the period of incapacity (all the medical certificates were examined for periods of incapacity of duration greater than 3 months) the sickness has been grouped under the major cause (some guidance was obtained from the Manual of the International List of Causes of Death, as used for the Classification of Deaths in England and Wales), or under the cause which was responsible for the main part of the time lost through the sickness. No difficulty was experienced in thus grouping the very great majority of the sicknesses, but in a small percentage some arbitrary rule had to be followed. For example such a diagnosis may have appeared as " influenza and rheumatism " and it is not possible to assign the sickness to Group I rather than to Group III, or vice versa. In such cases the same procedure was followed for each occupational group so that in comparison no fallacy exists. The rates for each occupational group from each cause of sickness have been calculated for ten-yearly age-groups with the exception of the group 16–19, which it was considered important to keep distinct in view of the previous findings. To retain five-yearly groups throughout would place too much reliance upon small numbers and the rates would continually show random fluctuations. Even in ten-yearly age groups care must be exercised in interpreting results, more especially for the smaller occupational divisions, e.g. the stereotypers, and not too much importance must be attached to individual rates Attention must be paid, rather, to the consistency with which the rates occupy any particular relative position *from age group to age group* or *from cause group to cause group*. To avoid a considerable multiplication of the tables it is not proposed to present the complete raw data—the days of sickness and disablement and number of claims for each cause group and each occupational group.

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* As far as possible, cases of workmen's compensation were excluded from the experience.

The rates derived from this material for each occupational division are given in Tables XXXIV to XLVI, and after each pair of rates—day rate and claim rate—has been inserted the number of claims upon which both rates depend, one directly and one indirectly. This figure gives some measure of the reliability of the rates. In addition in Table XXXI are set out the numbers exposed to risk in each ten-yearly age group and each occupational group. This table calls for no comment but should be utilised, in addition to the other checks suggested, when the significance of any rate is in question.

In Table XXXII, as a preliminary, are given the rates for all printers. In Table XXXIII these rates are expressed as percentages of the rates for all causes, so that a clear picture may be given of the relative importance of each cause of incapacity at each age. Reading the two tables in conjunction it is seen in short-period sickness (first 26 weeks) that the most important causes throughout insured life are influenza and diseases of the respiratory system. The former, in fact, from age 16 to age 49, accounts for approximately a quarter of all the claims made. Diseases of the respiratory system intensify in amount with age, owing partly to the increase in numbers of cases of chronic bronchitis. Other cause groups with appreciable proportions throughout life are the digestive group, the nervous group and the group entitled " other causes." Rheumatism, diseases of the respiratory system, of the circulatory system, of the nervous system and of the urinary system, all show their heaviest incidence in the later years of working life. On the other hand, diseases of the nasopharyngeal tract show a fall with age Diseases of the skin and accidents fall and then rise again, being at their lowest in middle life (but these differences are possibly not significant).

The unrecorded diseases and those of the reproductive system form totally unimportant groups and need have no attention paid to them. Gout has been kept as a separate group for the purpose of occupational comparisons. Some indication might be given, it was thought, of variations in incidence, suggesting a liability, in any occupational group, to "saturnine gout" due to lead-poisoning, a form from which, it has been asserted, printers suffer. The rates are unimportant until the final age groups.

Coming finally to phthisis, in short-period sickness this cause, naturally, does not play any predominant part, from age 16 to age 50 it accounts for some 9 per cent. of all the days of sickness lost and 3 per cent. of all the claims The rate is steady during this period of life, but falls appreciably after age 50. It is in the section of the table devoted to disablement that its importance becomes more apparent. From age 16 to age 39, phthisis and diseases of the nervous system are the only causes which produce any appreciable amount of long-period incapacity at all. In the first two age groups phthisis provides 40 to 45 per cent of all the days of disablement experienced and of all the claims made. In later life its relative importance diminishes owing to the rapid rise and the high rates attained in nervous diseases, rheumatism, "other causes," and diseases of the respiratory and circulatory system.

In long-period illness the diseases grouped under the nervous system are the most consistently important. They produce throughout insured life between 30 and 40 per cent. of all the days of disablement and approximately a quarter of all the claims. Rheumatism, "other causes," and diseases of the respiratory and circulatory systems, are only of distinct importance in the final age group, 60–69, where they exhibit very high rates. Influenza, diseases of the naso-pharyngeal tract, of the skin and of the reproductive system and accidents have no significance in long period incapacity. Diseases of the digestive and urinary systems have small importance, but a maximum perhaps worth attention at ages 60–69. Such is the experience for all printers.

Unfortunately no standard of comparison exists and whether the incidences of the various causes compare favourably or unfavourably with the experiences of a general population is a question which, at present, cannot be explored. The only method of investigation that remains is that already adopted for all causes of sickness—to compare the experience of each occupational group with that of all printers and with that of each other of the occupational groups. This is carried out in Tables XXXIV to XLVI, where each disease group is given in turn for all the occupational groups. Taking these tables one by one the conclusions suggested are as follows.

Influenza (Table XXXIV).—Cause Group I. The compositors show their initial high rate, at ages 16–19, from this cause. This position they share with stereotypers, bookbinders and lithographic printers. Machine printers and warehousemen, on the other hand, show relatively favourable rates in this age group (the last-named have too few exposed to risk at these ages and too few claims to give very reliable rates). From age 20 to age 49 compositors have low rates and machinemen in days of sickness compare unfavourably with them. Bookbinders and rulers show to the greatest advantage; they suffer appreciably less both in number of claims made and in amount of time lost from this cause throughout life. Lithographic printers show the converse and suffer unduly in every age group Warehousemen have a very high rate at age 30–39, but their rates show no consistent position. The main conclusion is that compositors derive their low rates in middle life for all causes partly from a low incidence of influenza; that similarly the higher rates of the machine printers in middle life come slightly from this cause, while the lower rates of the bookbinders and higher rates of the lithographic printers are distinct.

Phthisis (Table XXXV) —Cause Group 2. The high rate of the compositors in early life is here quite definite both in sickness and in disablement, and their excess is still apparent in the next age group, 20–29. After that age they have lower rates than all printers (much lower than the machine printers), but their position is again an adverse one in the final age group 60–69. For ages 16–19 their sickness rates are ·52 days and ·64 claims, those for *all other printers* are only ·31 days and ·25 claims. In disablement for the same age group their rates are ·78 days and ·60 claims; the rates for all other printers are ·04 days and ·15 claims. The evidence in this sample inquiry thus leads to the conclusion that the disadvantage shown by printers in tuberculosis mortality at the beginning of working life is to be attributed to compositors. For ages 20–29 their rates are still high in comparison with *all* printers, but bookbinders here rival them both in sickness and disablement experience (but their rates are based on only 14 claims). For the next age group, 30–39, the most striking factor is the relatively enormous rates of the warehousemen (it was in this age group that these workers suffered unduly from influenza, too), both day and claim rates being virtually twice as high as those for all printers (but these rates are based on only 22 claims). From age 40 to age 59 machine printers reveal part of the origin of their unenviable position as revealed for all causes of incapacity. In short-period sickness their rates are very much higher than those shown by any of the other occupational groups, being ·64 days and ·78 claims at age 40–49, against ·41 days and ·51 claims for all printers, and ·58 days and ·67 claims at age 50–59, against ·29 days and ·38 claims for all printers. In disablement their high rate at age 40–49 is shared by stereotypers, by bookbinders and by warehousemen, but in these cases the number of claims is small and the rates are unreliable. At ages 50–59 they are again uniquely and adversely placed. The high rate of the compositors at age 60–69 is striking. Lithographic machine printers show a very favourable experience from this disease throughout working life.

The conclusions provided by this table are, from the point of view of this inquiry, very important and further attention will be paid to this cause when the discussion of the other causes of sickness is concluded

Rheumatism (Table XXXVI) —Cause Group 3. Compositors again start with their initial high rate but have a favourable experience throughout the rest of life. Machine printers again start with an advantage which they lose by age 30, after which age their position is unfavourable. Stereotypers in this case share with them their higher incidence Bookbinders have a distinctly lower incidence in all age groups Warehousemen once more show their high rate at age 30–39—for short-period sickness only, the disablement experience being negligible in all cases until the final age group (the high rates at ages 16–19 are based only on 8 claims). Lithographic printers fluctuate in their rates but seem to show to disadvantage in this final age group when their sickness and disablement rates are both high.

Thus, as a whole, the usual tendencies are visible—viz. the bad "start" of the compositors followed by recovery; the heavier incidence amongst machine printers in later life; the lower rates of the bookbinders, and the high rate of warehousemen in the one age group 30–39.

Diseases of the Respiratory System (Table XXXVII) —Cause Group 4. In the initial five-yearly age group here (if the small experiences of the stereotypers and the warehousemen be dismissed as unreliable), there is little difference to be seen amongst the larger occupational groups. On the other hand, in later life compositors and bookbinders suffer consistently less and machine printers and warehousemen more from these illnesses The warehousemen do not show any abnormal rate in the 30–39 age group. The stereotypers and lithographic printers taking into account both rates, days and claims, and their fluctuations from age group to age group, cannot be said to reveal any very material departure from the rates for all printers

The general conclusion is that in this cause group the compositors, in conjunction with bookbinders, experience their usual lighter incidence while machine printers have their usual heavier incidence.

Diseases of the Naso-Pharyngeal and Upper Digestive Tract (Table XXXVIII).—Cause Group 5. This group is only of importance in the first three or four age groups and the disablement experience is entirely negligible. Compositors again are not alone in the early high rate, but their rates are very slightly higher than those of all other printers taken together. In each occupational group a fall occurs for ages 20–29. Only random fluctuations seem to be apparent and it cannot be said that for these diseases there is any great difference in incidence to be observed amongst the occupational groups.

Diseases of the Circulatory System (Table XXXIX).—Cause Group 6. These diseases do not show a very important incidence in early life and it is not until age 40 that the rates are at all appreciable. In short-period sickness the compositors show a relatively high initial rate ; stereotypers as a whole seem to have a light experience ; no other differences worth comment are apparent. In disablement the compositors show a final high rate, as do also the lithographic printers. Stereotypers again have a lighter incidence, and machine printers are not adversely affected The claims in each group are too few, taken as a whole, to make discussion justifiable

Diseases of the Digestive System (Table XL) —Cause Group 7. This is a cause group of more substantial proportions.

Compositors as usual begin life with a relatively high rate and afterwards have a more favourable experience than printers taken as a whole. For machine printers the converse is seen, the initial rate being low, the later rates uniformly high. With stereotypers the only distinct variation from the experience of all printers seems to lie in a heavy incidence in the last few years of insurance. Bookbinders share with the compositors the high rate at ages 16–19 and also their lighter experience in the rest of life. Warehousemen show some excess of incapacity from this cause after age 30. Lithographic printers, judging by both rates, show no material differences from the experience of all printers.

Diseases of the Nervous System (Table XLI).—Cause Group 8. This cause group provides an appreciable number of the sickness claims and a very large proportion of the disablement suffered. Compositors once more show an excess at ages 16–19 ; for the rest of life they do not hold their customary advantage but are roughly on a par with the all printers' group. Machine printers show no unfavourable experience. For stereotypers the number of claims is small and there are signs of mere random fluctuations, the rates moving up and down with the age groups and the days rate and claim rate giving reverse answers in comparison with the rates for all printers. No deduction of significant variation can be made. Much the same is true of the bookbinders and warehousemen. Lithographic printers, as a whole, have a heavier incidence from these diseases. All the occupational groups show a considerable amount of time lost from such causes, especially in the disablement rates after age 40, and it may be remembered that Table XXXIII showed that a quarter of all the disablement claims originated with these diseases.

Diseases of the Skin (Table XLII) —Cause Group 9 These illnesses have their highest incidences at the extremes of insured life. All the occupational types show a comparatively high claim rate at age group 16–19 and a lower rate in the following period. The compositors, however, in this case, show a relative advantage for the first age group. In later age groups much the usual tendencies are observable—the lighter incidence on compositors and bookbinders in mid-life, the higher rates of machine printers after age 40. The warehousemen's unfavourable position at ages 30–39 is in evidence, and this heavier incidence continues over the ages 40–59.

Diseases of the Urinary System (Table XLIII).—Cause Group 10. The incidence of these diseases is negligible before age 40. In these occupational groups throughout the number of claims is too small to be of very much value. The compositors seem to suffer unduly in the final age group, their rates being for sickness, ·57 days and 98 claims against ·30 days and ·55 claims for all other printers, and for disablement ·98 days and ·57 claims against ·46 days and ·27 claims for other printers , but it is possible that these differences are not significant

Diseases of the Reproductive System Cause Group 11 Table XXXII showed that the incapacity caused by these forms of illness was practically nil for all printers, so no occupational comparison is given

Other Causes (Table XLIV).—Cause Group 12. For this general group of causes of morbidity there is a uniformly high initial rate for all the occupational groups (the warehousemen excepted, of whom the exposed to risk is too small at these ages to give a satisfactory answer). The compositors are only slightly more unfavourably placed in this case and in this age group than are the other branches of the trade The chief causes for this period of life are the infectious diseases and ear and teeth troubles. The rates fall and remain lower in mid-life but rise again for the final age group 60–69, when such things as loss of sight, diabetes and cancer exhibit a greater frequency. In this mid-life period and in the final group, bookbinders have a relatively light incidence. Very little difference is to be observed between the other groups, either in sickness or disablement.

Accidents (Table XLV).—Cause Group 13. (This group as far as possible *excludes* cases that fall under the provisions of the Workmen's Compensation Act, and thus relates principally to accidents apart from the operatives' work.) The compositors do not show so high an initial rate as all printers but on the contrary are rather advantageously placed both in this group and throughout insured life. Machine printers are at a disadvantage after age 40. Stereotypers and lithographic printers show no significant differences. Bookbinders have a high rate at ages 16–19, and no other significant differences. Warehousemen and cutters have comparatively high rates throughout life. The disablement experience is slight and calls for no comment.

Gout (Table XLVI).—Cause Group 14. This form of illness is negligible in amount until after age 50, and the claims are few in number throughout. Compositors are in a slightly favourable position, machine printers the reverse. Stereotypers and electrotypers have definitely higher rates than all the other classes except warehousemen, who also are subject to a high incidence.

Unrecorded Causes.—Cause Group 15. These were very few in number and no table of comparison is needed.

TABLE XXXI.—*Numbers exposed to risk in ten-yearly Age Groups in each Occupational Group*, 1921–25.

Age Group. (Age last birthday at beginning of year of exposure.)	All Printers	Compositors.	Machine Printers	Stereotypers and Electrotypers	Bookbinders and Rulers.	Warehouse-men and Cutters	Lithographic Printers.
SICKNESS							
16–19	8,648	3,936	1,962	468	1,062	369	780
20–29	19,528	7,889	3,977	1,083	2,840	1,214	2,417
30–39	33,775	13,226	8,105	1,685	4,250	2,394	3,962
40–49	35,291	14,589	8,592	1,600	3,651	2,706	4,118
50–59	27,848	13,419	5,347	1,011	2,697	2,051	3,283
60–69	11,402	6,144	1,542	352	1,392	732	1,218
DISABLEMENT							
16–19	4,829	2,173	1,087	265	623	208	434
20–29	19,316	7,807	3,918	1,074	2,825	1,191	2,393
30–39	33,419	13,043	8,053	1,677	4,220	2,351	3,922
49–49	35,011	14,442	8,554	1,592	3,637	2,669	4,082
50–59	27,678	13,219	5,334	1,011	2,683	2,038	3,253
60–69	11,336	6,098	1,536	351	1,389	729	1,211

TABLE XXXII.—*Sickness Rates (first 26 weeks) and Disablement Rates (after 26 weeks) for All Printers, 1921–25, by Cause Groups.*

	Age Group.	Influenza. (1)			Phthisis (2)			Rheumatism (3)			Respiratory System. (4)			Naso-Pharyngeal Tract (5)			Circulatory System (6)		
		Day* rate.	Claim* rate	No of claims.	Day rate	Claim rate	No of claims	Day rate	Claim rate.	No of claims	Day rate.	Claim rate.	No of claims	Day rate	Claim rate	No of claims	Day rate	Claim rate	No of claims.
Sickness	16–19 ..	·81	5·47	473	·40	·43	37	·26	·90	78	·48	2 28	197	·31	2·31	200	15	52	45
	20–29 ..	·58	4·03	787	·36	·43	84	·17	·83	162	44	1 63	319	·16	1 21	237	·15	44	86
	30–39 ..	·68	4·39	1,482	·35	·49	166	·30	1 25	423	46	1·86	627	·14	95	321	19	52	175
	40–49 ..	·62	3·70	1,306	·41	·51	179	·48	1·92	678	·65	2 58	912	·09	·53	188	29	·78	274
	50–59 ..	·68	3 48	969	·29	·38	105	·59	2·51	698	1·22	4·14	1,153	·07	33	91	74	1 66	461
	60–69 ..	·77	3·32	379	·13	·16	18	1·44	3 74	426	2 68	6·89	786	·10	23	26	1·87	2 97	339
Disablement	16–19 ..	—	—	1	·37	·35	17	—	—	—	—	—	1	·01	·02	1	·02	·06	3
	20–29 ..	·01	02	4	·77	·40	78	—	—	—	·08	·08	16	—	—	2	02	03	5
	30–39 ..	—	—	9	86	·42	141	·01	·02	6	·14	·10	35	—	—	1	·16	·09	30
	40–49 ..	·01	·03	9	1·00	·50	176	·21	·10	35	·19	·18	63	—	—	3	32	·13	47
	50–59 ..	·02	·04	11	·65	·31	86	·24	·14	40	·69	·50	139	—	—	2	55	·33	92
	60–69 .	·06	·12	14	1·12	·43	49	3·14	1·29	146	4 64	2 30	261	04	·03	3	4·94	2 08	236

* The day rate is days of sickness (or disablement) per person-year of exposure The claim rate is number of claims made per 100 person-years of exposure in each case No rate is shown unless both are more than ·01.

TABLE XXXII—*continued*

	Age Group	Digestive System (7)			Nervous System (8)			Skin (9)			Urinary System (10)			Reproductive System (11)		
		Day rate	Claim rate	No. of claims	Day rate	Claim rate	No of claims	Day rate.	Claim rate	No of claims	Day rate	Claim rate	No of claims	Day rate	Claim rate	No of claims
Sickness	16–19 ..	44	1·58	137	·31	71	61	35	2 16	187	·06	15	13	02	·08	7
	20–29 .	·43	1·54	301	·25	64	125	·22	1 18	231	·03	13	26	·02	·09	17
	30–39 ..	42	1·48	500	·32	·77	260	·19	·94	319	·07	22	73	·01	06	20
	40–49 ..	·62	1·77	624	·44	·92	324	23	·99	350	12	29	103	·02	·05	18
	50–59 ..	·67	2 08	580	·61	1 12	311	29	1·10	306	17	36	100	·02	06	18
	60–69 ..	·78	2·25	256	1·60	2 46	280	·37	1·11	126	45	78	89	02	·04	5
Disablement	16–19 ..	·04	·04	2	·32	·13	6	—	—	—	12	04	2	—	—	—
	20–29 ..	·04	·06	12	62	·24	46	08	·04	7	·01	01	2	—	—	—
	30–39 ..	07	·07	23	·82	·32	106	·03	·01	5	·01	·02	8	—	—	—
	40–49 ..	·15	·14	48	1·07	·43	152	—	—	5	·02	·03	9	—	—	—
	50–59 ..	·14	·13	36	2·36	·85	234	·05	·09	24	10	08	23	—	—	—
	60–69 ..	·97	·44	50	6·51	2 48	281	·07	06	7	·74	·43	49	—	—	—

TABLE XXXII.—*continued.*

Age Group.		Other Causes. (12)			Accidents (13)			Gout. (14)			Unrecorded. (15)			All Causes (16)		
		Day rate	Claim rate.	No of claims	Day rate	Claim rate	No of claims	Day rate	Claim rate	No of claims	Day rate	Claim rate	No of claims	Day rate	Claim rate	No of claims.
Sickness	16–19 .	·69	2·64	228	·37	1·97	170	—	—	1	01	·03	3	4 68	21·24	1,837
	20–29 . .	·32	1·37	268	·34	1·13	221	—	—	1	·05	·11	22	3·53	14 78	2,887
	30–39 . .	·32	1·27	429	·21	·79	267	01	·07	25	·05	·13	44	3 74	15·19	5,131
	40–49 . .	·44	1·36	481	·29	·95	337	·07	·43	152	·04	·12	44	4·81	16 92	5,970
	50–59 . .	·71	1·77	492	·39	1·19	332	·19	1 09	304	·03	·08	22	6 66	21·34	5,942
	60–69 . .	1·23	2·22	253	·46	1·37	156	·27	1·00	114	·09	·19	22	12 26	28·72	3,275
Disablement	16–19 . .	·04	08	4	—	—	—	—	—	—	—	—	—	92	·77	37
	20–29 .	·04	04	8	·05	·06	11	—	—	—	—	—	1	1·72	·99	192
	30–39 . .	·08	·07	22	·05	·04	14	—	—	—	·06	·02	7	2·30	1·22	407
	40–49 . .	·45	·20	71	·05	·05	17	—	—	7	—	—	2	3·48	1·84	644
	50–59 . .	97	·43	118	·09	·07	19	·01	07	20	·02	·01	4	5 89	3 06	848
	60–69 .	2·18	·95	108	·09	·12	14	·29	·15	17	·15	·06	7	24·93	10 96	1,242

TABLE XXXIII.—*Sickness Rates* (*first* 26 *weeks*) *and Disablement Rates* (*after* 26 *weeks*) *for All Printers*, 1921–25, *by Cause Groups, the Rates for* **each** *Cause being expressed as percentages of the corresponding Rates for* **all** *Causes.**

Age Group.		Influenza. (1)		Phthisis. (2)		Rheumatism (3)		Respiratory System. (4)		Naso-Pharyngeal Tract (5)		Circulatory System (6)		Digestive System (7)	
		Day rate	Claim rate.	Day rate.	Claim rate.	Day rate	Claim rate.	Day rate.	Claim rate.	Day rate.	Claim rate	Day rate	Claim rate.	Day rate	Claim rate.
Sickness	16–19 . .	17	26	9	2	6	4	10	11	7	11	3	2	9	7
	20–29 . .	16	27	10	3	5	6	12	11	5	8	4	3	12	10
	30–39 . .	18	29	9	3	8	8	12	12	4	6	5	3	11	10
	40–49 . .	13	22	9	3	10	11	14	15	2	3	6	5	13	10
	50–59 . .	10	16	4	2	9	12	18	19	1	2	11	8	10	10
	60–69 . .	6	12	1	1	12	13	22	24	1	1	15	10	6	8
Disablement	16–19 . .	—	—	40	45	—	—	—	—	1	3	2	8	4	5
	20–29 . .	1	2	45	40	—	—	5	8	—	—	1	3	2	6
	30–39 . .	—	—	37	34	—	—	6	8	—	—	7	7	3	6
	40–49 . .	—	—	29	27	6	5	5	10	—	—	9	7	4	8
	50–59 . .	—	—	11	10	4	5	12	16	—	—	9	11	2	4
	60–69 . .	—	—	4	4	13	12	19	21	—	—	20	19	4	4

* This Table reads : Of the sickness suffered from *all* causes influenza was responsible at age 16–19 for 17 per cent of the days lost and for 26 per cent. of the claims made , phthisis was responsible for 9 per cent. of the days lost and for 2 per cent of the claims made , and so on for each age and for each disease.

TABLE XXXIII—*continued.*

Age Group.		Nervous System. (8)		Skin (9)		Urinary System. (10)		Reproductive System (11)		Other Causes (12)		Accidents. (13)		Gout. (14)		Unrecorded. (15)	
		Day rate.	Claim rate.	Day rate	Claim rate.	Day rate.	Claim rate.	Day rate.	Claim rate.	Day rate.	Claim rate.	Day rate.	Claim rate	Day rate.	Claim rate.	Day rate.	Claim rate
Sickness	16–19	7	3	7	10	1	1	—	—	15	12	8	9	—	—	—	—
	20–29	7	4	6	8	1	1	1	1	9	9	10	8	—	—	1	1
	30–39	9	5	5	6	2	1	—	—	9	8	6	5	—	—	1	1
	40–49	9	5	5	6	2	2	—	—	9	8	6	6	1	3	1	1
	50–59	9	5	4	5	3	2	—	—	11	8	6	6	3	5	—	—
	60–69	13	9	3	4	4	3	—	—	10	8	4	5	2	3	1	1
Disablement	16–19	35	17	—	—	13	5	—	—	4	10	—	—	—	—	—	—
	20–29	36	24	5	4	1	1	—	—	2	4	3	6	—	—	—	—
	30–39	36	26	1	1	—	—	—	—	3	6	2	3	—	—	3	2
	40–49	31	23	—	—	1	2	—	—	13	11	1	3	—	—	—	—
	50–59	40	28	1	3	2	3	—	—	16	14	2	2	—	—	—	—
	60–69	26	23	—	—	3	4	—	—	9	9	—	—	1	1	1	1

TABLE XXXIV.—*Sickness rates* (*first* 26 *weeks*) *and Disablement rates* (*after* 26 *weeks*) *for All Printers and for each Occupational Group for* 1921–25 *from INFLUENZA.*

(*Cause Group* 1.)

	Age Group *	All Printers		Compositors		Machine Printers		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
		Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡
Sickness	16–19	81	5 47 (473)	91	5·94 (234)	63	4 79 (94)	·94	6·62 (31)	80	4 80 (51)	35	2 44 (9)	95	6 79 (53)
	20–29	58	4 03 (787)	57	4 30 (339)	69	4 15 (165)	60	4·80 (52)	46	2 99 (85)	37	2 72 (33)	77	4 59 (111)
	30–39	·68	4 39 (1482)	59	4 17 (551)	71	4 21 (341)	·60	4 15 (70)	55	3 91 (166)	98	4·89 (117)	95	5 88 (233)
	40–49	62	3 70 (1306)	56	3 55 (518)	72	4 03 (346)	59	3 19 (51)	49	2 82 (103)	65	3 62 (98)	73	4 52 (186)
	50–59	68	3 48 (969)	69	3 66 (491)	64	3 27 (175)	58	3·56 (36)	60	2 97 (80)	61	2 44 (50)	·84	4 14 (136)
	60–69	77	3 32 (379)	·73	3 21 (197)	81	3 76 (58)	29	1 13 (4)	69	2 59 (36)	1 18	4 10 (30)	94	4 35 (53)
Disablement	16–19	—	— (1)	—	— —	—	— —	—	— —	·03	·16 (1)	—	— —	—	— —
	20–29	·01	·02 (4)	—	— —	01	·05 (2)	—	— —	02	04 (1)	—	— —	—	— (1)
	30–39	—	— (9)	—	— (1)	01	06 (5)	—	— —	01	05 (2)	—	— —	—	— (1)
	40–49	·01	·03 (9)	01	05 (7)	—	— (1)	—	— —	01	03 (1)	—	— —	—	— —
	50–59	·02	·04 (11)	·01	02 (3)	01	04 (2)	—	— —	01	07 (2)	·08	·10 (2)	01	06 (2)
	60–69	06	12 (14)	·05	07 (4)	·08	·20 (3)	—	— —	—	— —	04	·14 (1)	20	50 (6)

The bracketed figures are the actual number of claims made which allow some consideration of the significance of the rates

* Age last birthday at beginning of year of exposure

† In days per person-year of exposure

‡ In claims per 100 person-years of exposure.

TABLE XXXV.—*Sickness Rates (first 26 weeks) and Disablement Rates (after 26 weeks) for All Printers and for each Occupational Group for* 1921–25 *from PHTHISIS.*

(Cause Group 2 *)*

	Age Group.*	All Printers		Compositors		Machine Printers		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
		Day rate †	Claim rate.‡	Day rate.†	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate.‡	Day rate.†	Claim rate ‡	Day rate †	Claim rate.‡	Day rate.†	Claim rate ‡
Sickness	16–19	·40	·43 (37)	·52	·64 (25)	·36	·30 (6)	—	— —	·34	·28 (3)	·50	·27 (1)	·24	·26 (2)
	20–29	36	·43 (84)	47	·56 (44)	·26	·33 (13)	·03	·09 (1)	·50	49 (14)	·46	58 (7)	13	17 (4)
	30–39	·35	·49 (166)	28	·47 (62)	·38	·56 (45)	17	·30 (5)	·32	·38 (16)	·71	·92 (22)	·40	·40 (16)
	40–49	·41	·51 (179)	·31	·42 (61)	·64	·78 (67)	·45	·31 (5)	·39	·44 (16)	34	·44 (12)	·30	36 (15)
	50–59	·29	·38 (105)	·22	·27 (36)	·58	·67 (36)	·22	·20 (2)	·31	·52 (14)	10	·34 (7)	25	30 (10)
	60–69	·13	·16 (18)	·22	·26 (16)	·12	·13 (2)	—	— —	—	— —	—	— —	—	— —
Disablement	16–19	37	·35 (17)	78	·60 (13)	—	— —	—	— —	10	·48 (3)	15	48 (1)	—	— —
	20–29	·77	·40 (78)	·98	·50 (39)	·56	31 (12)	—	— —	98	·50 (14)	·51	·25 (3)	·61	·29 (7)
	30–39	·86	·42 (141)	·84	40 (52)	74	42 (34)	·72	24 (4)	·79	·38 (16)	1·78	·81 (19)	·76	·41 (16)
	40–49	1·00	50 (176)	59	·30 (44)	1·16	·67 (57)	2·12	·82 (13)	1·65	·74 (27)	1·67	·63 (17)	·56	·39 (16)
	50–59	·65	·31 (86)	·48	·23 (30)	1·37	·52 (28)	94	30 (3)	48	·22 (6)	·20	44 (9)	·51	·31 (10)
	60–69	1·12	·43 (49)	1·76	·62 (38)	·15	·26 (4)	—	— —	1·23	·50 (7)	—	— —	—	— —

The bracketed figures are the actual number of claims made which allow some consideration of the significance of the rates

* Age last birthday at beginning of year of exposure

† In days per person-year of exposure.

‡ In claims per 100 person-years of exposure.

TABLE XXXVI.—*Sickness Rates (first 25 weeks) and Disablement Rates (after 26 weeks) for All Printers and for each Occupational Group for* 1921–25, *from RHEUMATISM.*

(*Cause Group* 3.)

	Age Group.*	All Printers		Compositors		Machine Printers		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
		Day rate.†	Claim rate.‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate.†	Claim rate.‡	Day rate †	Claim rate.‡
Sickness	16–19	·26	·90 (78)	·32	97 (38)	·18	·87 (17)	·06	·43 (2)	·08	·47 (5)	·65	2·17 (8)	·35	1·03 (8)
	20–29	·17	·83 (162)	·18	·91 (72)	·18	·18 (32)	·21	·92 (10)	·09	·42 (12)	·23	·91 (11)	·20	1·03 (25)
	30–39	·30	1·25 (423)	·26	·99 (131)	42	1·79 (145)	·18	1·42 (24)	·20	82 (35)	·41	1·59 (38)	·31	1·26 (50)
	40–49	·48	1·92 (678)	·37	1 54 (224)	·70	2 60 (223)	70	2·81 (45)	·34	1·34 (49)	·52	2·11 (57)	·39	1·87 (77)
	50–59	·59	2 51 (698)	·45	1 95 (261)	·89	3·59 (192)	·74	3·36 (34)	·33	1·63 (44)	·77	2·83 (58)	·72	3·23 (106)
	60–69	1·44	3·74 (426)	1·34	3·11 (191)	1·80	5·51 (85)	1·65	4·26 (15)	1·39	3 02 (42)	1·23	4·64 (34)	1·62	4·84 (59)
Disablement	16–19	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —
	20–29	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —
	30–39	·01	·02 (6)	·02	·02 (2)	·02	·01 (1)	—	— —	—	— (1)	·01	·09 (2)	—	— —
	40–49	·21	·10 (35)	·05	·03 (5)	·34	·21 (18)	·41	·25 (4)	·33	·11 (4)	—	— —	·45	·12 (5)
	50–59	·24	·14 (40)	·17	·09 (12)	·52	·30 (16)	—	— —	·05	·07 (2)	·12	·25 (5)	·40	·15 (5)
	60–69	3·14	1·29 (146)	3·16	1·31 (80)	3·68	1·50 (23)	1·45	·57 (2)	3·22	1·08 (15)	·78	1·23 (9)	4·19	1·40 (17)

The bracketed figures are the actual number of claims made which allow some consideration of the significance of the rates

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure

‡ In claims per 100 person-years of exposure.

TABLE XXXVII.—*Sickness Rates (first 26 weeks) and Disablement Rates (after 26 weeks) for All Printers and for each Occupational Group for 1921–25 from Diseases of the RESPIRATORY SYSTEM.*

(*Cause Group* 4.)

	Age Group.*	All Printers		Compositors.		Machine Printers		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
		Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡
Sickness	16–19	48	2 28 (197)	·50	2·44 (96)	·58	2·45 (48)	·18	1·28 (6)	·48	2·17 (23)	·24	1·62 (6)	47	2 05 (16)
	20–29	·44	1·63 (319)	·32	1 43 (113)	·69	2 16 (86)	·39	1·20 (13)	·36	1·34 (38)	·73	2 22 (27)	·40	1·65 (40)
	30–39	·46	1·86 (627)	·42	1 68 (222)	63	2 27 (184)	·56	2 43 (41)	·39	1 44 (61)	·53	1 92 (46)	29	1·79 (71)
	40–49	·65	2·58 (912)	46	2·10 (306)	·98	3·42 (294)	·58	2·62 (42)	·47	1 67 (61)	·77	3 07 (83)	·71	2·99 (123)
	50–59	1·22	4·14 (1153)	·94	3·53 (474)	2·07	5·84 (312)	1·59	5 54 (56)	1·11	3·78 (102)	1 20	4 09 (84)	98	3 69 (121)
	60–69	2·68	6 89 (786)	2 37	6·43 (395)	2 89	7·39 (114)	2 74	8 80 (31)	2·86	6 03 (84)	4 25	10 24 (75)	2 86	7·14 (87)
Disablement	16–19	—	— (1)	—	— (1)	—	— —	—	— —	—	— —	—	— —	—	— —
	20–29	·08	·08 (16)	·02	·04 (3)	·17	·15 (6)	—	— —	—	— —	·56	·42 (5)	·02	·08 (2)
	30–39	·14	·10 (35)	·13	08 (10)	·22	21 (17)	—	— —	·10	·09 (4)	·38	17 (4)	—	— —
	40–49	·19	·18 (63)	·03	·05 (7)	18	·15 (13)	·32	·69 (11)	·72	36 (13)	50	37 (10)	·12	·22 (9)
	50–59	·69	·50 (139)	·36	·20 (27)	1·07	1·14 (61)	1·42	·99 (10)	·60	·52 (14)	·70	·59 (12)	1·27	46 (15)
	50–69	4·64	2·30 (261)	4·68	2·12 (129)	2·89	1·56 (24)	8·59	8·25 (29)	6·45	2·95 (41)	3·13	2·61 (19)	4·36	1·57 (19)

The bracketed figures are the actual number of claims made which allow some consideration of the significance of the rates.

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure.

‡ In claims per 100 person-years of exposure.

TABLE XXXVIII.—*Sickness Rates (first 26 weeks) and Disablement Rates (after 26 weeks) for All Printers and for each Occupational Group for 1921–25 from Diseases of the NASO-PHARYNGEAL and UPPER DIGESTIVE TRACT.*

(Cause Group 5.)

	Age Group.*	All Printers		Compositors		Machine Printers		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
		Day rate.†	Claim rate ‡	Day rate.†	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate.†	Claim rate ‡
Sickness	16–19	·31	2 31 (200)	·34	2 46 (97)	24	1·94 (38)	·44	2·99 (14)	·31	2 45 (26)	·36	2 17 (8)	26	2 18 (17)
	20–29	16	1·21 (237)	16	1 25 (99)	15	1·01 (40)	·20	1·85 (20)	·12	1·02 (29)	·19	1·40 (17)	·18	1·20 (29)
	30–39	·14	·95 (321)	11	·86 (114)	15	1·09 (88)	29	1·60 (27)	·13	·68 (29)	·11	·96 (23)	14	1 01 (40)
	40–49	09	53 (188)	·08	·54 (79)	10	52 (45)	04	37 (6)	10	60 (22)	·14	67 (18)	06	41 (17)
	50–59	07	·33 (91)	05	·31 (41)	·09	36 (19)	·02	·30 (3)	13	·33 (9)	·13	49 (10)	05	·27 (9)
	60–69	·10	·23 (26)	·12	·23 (14)	·13	·32 (5)	·08	·28 (1)	·04	·22 (3)	·14	·27 (2)	02	·08 (1)
Disablement	16–19	·01	·02 (1)	—	— —	·02	·09 (1)	—	— —	—	— —	—	— —	—	— —
	20–29	—	— (2)	—	— —	—	— —	—	— —	01	·07 (2)	—	— —	—	— —
	30–39	—	— (1)	—	— —	—	— —	·01	·06 (1)	—	— —	—	— —	—	— —
	40–49	—	— (3)	—	— —	—	— (2)	—	— —	—	— (1)	—	— —	—	— —
	50–59	—	— (2)	—	— —	—	— (1)	—	— —	·03	·04 (1)	—	— —	—	— —
	60–69	·04	·03 (3)	·07	·05 (3)	—	— —	—	— —	—	— —	—	— —	—	— —

The bracketed figures are the actual number of claims made which allow some consideration of the significance of the rates.

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure.

‡ In claims per 100 person-years of exposure.

TABLE XXXIX.—*Sickness Rates (first* 26 *weeks) and Disablement Rates (after* 26 *weeks) for All Printers and for each Occupational Group for* 1921–25 *from Diseases of the CIRCULATORY SYSTEM*

(*Cause Group* 6.)

	Age Group.*	All Printers.		Compositors		Machine Printers.		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
		Day rate †	Claim rate ‡	Day rate †	Claim rate.‡	Day rate.†	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡
Sickness	16–19	·15	·52 (45)	·22	·58 (23)	·10	·41 (8)	·10	·64 (3)	14	·66 (7)	—	— —	04	·26 (2)
	20–29	·15	·44 (86)	14	·39 (31)	·14	·48 (19)	·03	28 (3)	·21	·53 (15)	·08	·41 (5)	24	·54 (13)
	30–39	19	·52 (175)	14	·45 (60)	·22	57 (46)	·03	·12 (2)	23	·68 (29)	·34	·50 (12)	·25	·66 (26)
	40–49	29	78 (274)	·28	·81 (118)	·36	·85 (73)	·14	·56 (9)	·26	·77 (28)	·41	·74 (20)	·18	61 (25)
	50–59	·74	1·66 (461)	·73	1·67 (224)	·70	1·72 (92)	76	1 29 (13)	·71	1·59 (43)	·74	1 51 (31)	·85	1·77 (58)
	60–69	1·87	2·97 (339)	1·99	3·06 (188)	1 69	2 72 (42)	·90	1 99 (7)	1·91	3 45 (48)	2 03	2 87 (21)	1 61	2 63 (32)
Disablement	16–19	·02	06 (3)	·04	·05 (1)	—	— (1)	—	— —	·02	·16 (1)	—	— —	—	— —
	20–29	·02	·03 (5)	—	— —	—	— —	—	— —	·06	07 (2)	02	·08 (1)	11	·08 (2)
	30–39	·16	·09 (30)	·16	·06 (8)	·12	·10 (8)	—	— —	·02	·02 (1)	·87	38 (9)	·07	10 (4)
	40–49	·32	13 (47)	·21	·09 (13)	·05	·09 (8)	—	— —	69	·19 (7)	1·26	41 (11)	50	·17 (7)
	50–59	·55	33 (92)	·55	·34 (45)	·34	·24 (13)	·71	40 (4)	·46	·30 (8)	·87	39 (8)	·70	·43 (14)
	60–69	4·94	2·08 (236)	6·01	2·36 (144)	3·47	1·76 (27)	·81	·57 (2)	3·02	1·73 (24)	3·70	1·51 (11)	5 63	2 31 (28)

The bracketed figures are the actual number of claims made which allow some consideration of the significance of the rates

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure.

‡ In claims per 100 person-years of exposure.

TABLE XL.—*Sickness Rates (first 26 weeks) and Disablement Rates (after 26 weeks) for All Printers and for each Occupational Group for* 1921–25 *from Diseases of the DIGESTIVE SYSTEM*

(*Cause Group* 7.)

	Age Group *	All Printers		Compositors		Machine Printers		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
		Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡
Sickness	16–19	·44	1 58 (137)	·52	1 80 (71)	·33	1 32 (26)	·49	1·28 (6)	58	1·98 (21)	·22	1 08 (4)	·18	1 03 (8)
	20–29	·43	1·54 (301)	·39	1 47 (116)	·44	1·31 (52)	·59	2 03 (22)	38	1 44 (41)	37	1 73 (21)	53	1 99 (48)
	30–39	·42	1·48 (500)	35	1 33 (176)	·57	1·95 (158)	30	·77 (13)	·38	1 08 (46)	66	1 67 (40)	31	1 64 (65)
	40–49	·62	1 77 (624)	·53	1·67 (244)	·82	2 16 (186)	65	1 62 (26)	32	96 (35)	·83	2 18 (59)	·60	1 77 (73)
	50–59	·67	2·08 (580)	59	1 91 (256)	86	2 43 (130)	1 12	3·36 (34)	47	1·45 (39)	72	2 14 (44)	·66	2·28 (75)
	60–69	·78	2·25 (256)	·69	2 05 (126)	1 01	2 27 (35)	1·96	5·39 (19)	·70	1·36 (19)	·56	3·00 (22)	·85	2·63 (32)
Disablement	16–19	·04	·04 (2)	—	— —	01	·09 (1)	—	— —	·32	·16 (1)	—	— —	—	— —
	20–29	·04	·06 (12)	—	— (1)	·08	·13 (5)	—	— —	·04	·11 (3)	·24	08 (1)	03	08 (2)
	30–39	·07	07 (23)	·04	·06 (8)	·19	07 (6)	—	— —	·05	09 (4)	07	21 (5)	—	— —
	40–49	·15	·14 (48)	·21	·12 (17)	20	20 (17)	—	— —	·06	19 (7)	·10	15 (4)	02	·07 (3)
	50–59	·14	·13 (36)	17	11 (15)	11	17 (9)	·36	·10 (1)	·09	·22 (6)	06	·05 (1)	·08	·12 (4)
	60–69	·97	·44 (50)	57	·33 (20)	3·07	1·04 (16)	2·16	1·14 (4)	1·48	·65 (9)	—	— —	03	·08 (1)

The bracketed figures are the actual number of claims made which allow some consideration of the significance of the rates.

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure.

‡ In claims per 100 person-years of exposure

TABLE XLI.—*Sickness Rates (first 26 weeks) and Disablement Rates (after 26 weeks) for All Printers and for each Occupational Group for* 1921–25 *from Diseases of the NERVOUS SYSTEM.*

(*Cause Group* 8.)

	Age Group.*	All Printers.		Compositors.		Machine Printers		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers.	
		Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate.†	Claim rate.‡	Day rate.†	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡
Sickness	16–19	·31	·71 (61)	·39	·76 (30)	·19	·61 (12)	19	1 07 (5)	·18	·47 (5)	·02	·27 (1)	·41	·51 (4)
	20–29	·25	·64 (125)	·25	·65 (51)	26	·60 (24)	19	·74 (8)	·19	·49 (14)	·04	33 (4)	33	·83 (20)
	30–39	·32	·77 (260)	·26	·72 (95)	·36	·84 (68)	·46	1 01 (17)	34	·71 (30)	·22	·63 (15)	·38	83 (33)
	40–49	·44	·92 (324)	·35	·85 (124)	·47	·90 (77)	66	1·12 (18)	·54	·88 (32)	·47	92 (25)	49	1·17 (48)
	50–59	·61	1·12 (311)	·65	1·16 (156)	·48	·94 (50)	·32	·89 (9)	·83	1 08 (29)	·51	1·17 (24)	59	1 31 (43)
	60–69	1 60	2·46 (280)	1 63	2·36 (145)	1·46	2 72 (42)	1 20	1 70 (6)	1·87	2·37 (33)	·71	1 64 (12)	1 79	3·28 (40)
Disablement	16–19	·32	·13 (6)	·64	·18 (4)	—	— —	—	— —	—	— —	—	— —	32	46 (2)
	20–29	·62	·24 (46)	·36	·14 (11)	·73	·36 (14)	—	— —	·81	·25 (7)	1 30	·50 (6)	1·02	·33 (8)
	30–39	82	·32 (106)	1·06	·34 (44)	·90	·34 (27)	·51	·30 (5)	·68	·36 (15)	·11	·09 (2)	62	·33 (13)
	40–49	1·07	·43 (152)	1·14	·46 (66)	1·01	·40 (34)	04	·13 (2)	2·20	80 (29)	·47	·22 (6)	74	·37 (15)
	50–59	2·36	·85 (234)	2·39	·84 (111)	1·51	·56 (30)	1·10	·40 (4)	3·24	1·16 (31)	2·96	·98 (20)	3·05	1·17 (38)
	60–69	6·51	2·48 (281)	7·63	2·85 (174)	4·76	1·76 (27)	5·31	2·28 (8)	6·36	2 30 (32)	1·78	·96 (7)	6·59	2·56 (31)

The bracketed figures are the actual number of claims made which allow some consideration of the significance of the rates

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure.

‡ In claims per 100 person-years of exposure.

TABLE XLII.—*Sickness Rates (first 26 weeks) and Disablement Rates (after 26 weeks) for All Printers and for each Occupational Group for* 1921–25 *from Diseases of the SKIN.*

(*Cause Group* 9.)

	Age Group *	All Printers.		Compositors.		Machine Printers		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
		Day rate.†	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡
Sickness	16–19	·35	2·16 (187)	·30	1 85 (73)	·46	2 45 (48)	·46	3·42 (16)	27	1 79 (19)	57	4 33 (16)	·24	1·79 (14)
	20–29	·22	1·18 (231)	·22	1 19 (94)	21	1 31 (52)	·18	1·11 (12)	·22	·99 (28)	·22	1·24 (15)	27	1 16 (28)
	30–39	·19	·94 (319)	·15	83 (110)	·19	94 (76)	·32	1·54 (26)	·11	·47 (20)	42	1 46 (35)	22	1 31 (52)
	40–49	·23	·99 (350)	19	·82 (119)	31	1 26 (108)	22	1·19 (19)	11	66 (24)	40	1 26 (34)	25	1 09 (45)
	50–59	·29	1·10 (306)	·28	1·02 (137)	40	1·37 (73)	·11	·79 (8)	·14	74 (20)	39	1 27 (26)	·29	1 28 (42)
	60–69	·37	1·11 (126)	27	1·03 (63)	·52	1·49 (23)	·05	·28 (1)	·59	1·15 (16)	61	1 09 (8)	·37	1·23 (15)
Disablement	16–19	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —
	20–29	·08	·04 (7)	—	— —	—	— —	—	— —	·40	·14 (4)	—	— —	·19	·13 (3)
	30–39	·03	·01 (5)	—	— (1)	—	— —	·14	·12 (2)	—	— —	·23	·09 (2)	·09	03 (1)
	40–49	—	— (5)	·01	·03 (4)	—	— (1)	—	— —	—	— —	—	— —	—	— —
	50–59	·05	·09 (24)	·08	·11 (14)	·01	·07 (4)	—	— —	—	— —	·05	10 (2)	09	·12 (4)
	60–69	·07	·06 (7)	·06	05 (3)	·04	·07 (1)	—	— —	20	·14 (2)	·11	·14 (1)	—	— —

The bracketed figures are the actual number of claims made which allow some consideration of the significance of the rates

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure.

‡ In claims per 100 person-years of exposure.

TABLE XLIII.—*Sickness Rates (first 26 weeks) and Disablement Rates (after 26 weeks) for All Printers and for each Occupational Group for* 1921–25 *from Diseases of the URINARY SYSTEM.*

(*Cause Group* 10.)

	Age Group.*	All Printers		Compositors		Machine Printers		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
		Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate.†	Claim rate.‡	Day rate.†	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡
Sickness	16–19	·06	·15 (13)	·05	·10 (4)	·11	·20 (4)	—	— —	·03	·19 (2)	·11	·54 (2)	—	— —
	20–29	·03	·13 (26)	·05	14 (11)	·04	·23 (9)	—	— —	—	— (1)	—	— (1)	·02	·17 (4)
	30–39	·07	·22 (73)	·08	·22 (29)	·06	·20 (16)	·08	·36 (6)	·02	·07 (3)	·15	38 (9)	·06	23 (9)
	40–49	·12	·29 (103)	·16	·34 (50)	·10	·28 (24)	·03	·12 (2)	·12	·30 (11)	·09	·22 (6)	·11	·24 (10)
	50–59	·17	·36 (100)	·14	·34 (45)	·20	·41 (22)	·16	·30 (3)	·14	·26 (7)	·22	·29 (6)	·16	49 (16)
	60–69	·45	·78 (89)	·57	·98 (60)	·17	·32 (5)	—	— —	16	·29 (4)	·28	·55 (4)	·71	1·31 (16)
Disablement	16–19	·12	·04 (2)	—	— —	·55	·18 (2)	—	— —	—	— —	—	— —	—	— —
	20–29	·01	·01 (2)	·01	·01 (1)	·04	·03 (1)	—	— —	—	— —	—	— —	—	— —
	30–39	·01	·02 (8)	·01	·03 (4)	—	— —	—	— —	·01	·02 (1)	·07	·09 (2)	—	— —
	40–49	·02	·03 (9)	·03	·03 (4)	02	·06 (5)	—	— —	—	— —	—	— —	—	— —
	50–59	·10	·08 (23)	·16	·11 (14)	·06	·06 (3)	—	— —	·05	·11 (3)	07	05 (1)	·01	·06 (2)
	60–69	·74	43 (49)	·98	·57 (35)	·39	·26 (4)	—	— —	·33	·14 (2)	·09	·14 (1)	1·07	·58 (7)

The bracketed figures are the actual number of claims made which allow some consideration of the significance of the rates.

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure

‡ In claims per 100 person-years of exposure.

TABLE XLIV.—*Sickness Rates (first 26 weeks) and Disablement Rates (after 26 weeks) for All Printers and for each Occupational Group for* 1921–25 *from "OTHER CAUSES"*.

(*Cause Group* 12)

	Age Group.*	All Printers		Compositors		Machine Printers.		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
		Day rate.†	Claim rate ‡	Day rate.†	Claim rate ‡	Day rate †	Claim rate ‡	Day rate.†	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡
Sickness	16–19	·69	2·64 (228)	·75	2 67 (105)	·68	2·90 (57)	·52	2·35 (11)	·74	2·35 (25)	·18	1 62 (6)	·73	3·08 (24)
	20–29	·32	1·37 (268)	·29	1·32 (104)	·32	1·46 (58)	·34	1·66 (18)	·36	·88 (25)	·44	1 81 (22)	·29	1·53 (37)
	30–39	·32	1·27 (429)	·30	1·32 (175)	·43	1·38 (112)	·26	1·19 (20)	·17	·80 (34)	·37	1·25 (30)	·33	1·44 (57)
	40–49	·44	1·36 (481)	·42	1·40 (204)	·55	1·44 (124)	·24	1·00 (16)	·34	1·07 (39)	37	1·07 (29)	·53	1·68 (69)
	50–59	·71	1·77 (492)	69	1·84 (247)	·69	1·66 (89)	1·12	2·27 (23)	·58	1·26 (34)	·80	1·32 (27)	·65	2·10 (69)
	60–69	1·23	2 22 (253)	1·40	2·21 (136)	1·37	2·79 (43)	1·28	3·69 (13)	·80	1·72 (24)	·72	1·50 (11)	·99	1·97 (24)
Disablement	16–19	·04	·08 (4)	01	·05 (1)	·08	·09 (1)	—	— —	·07	·16 (1)	—	— —	·06	·23 (1)
	20–29	·04	·04 (8)	—	— (1)	·01	·05 (2)	—	— —	·13	·07 (2)	·04	·08 (1)	·13	·08 (2)
	30–39	·08	·07 (22)	·01	·02 (2)	·02	·07 (6)	—	— —	·04	·05 (2)	·25	·21 (5)	·40	·18 (7)
	40–49	·45	·20 (71)	·63	·26 (38)	·33	·16 (14)	·17	·19 (3)	·19	·08 (3)	51	·19 (5)	·34	·20 (8)
	50–59	·97	·43 (118)	·81	·39 (51)	1·36	·56 (30)	·60	·59 (6)	62	·19 (5)	1·80	·69 (14)	86	·37 (12)
	60–69	2 18	·95 (108)	3·27	1·36 (83)	·97	·52 (8)	1·10	·57 (2)	1·07	·50 (7)	·21	·14 (1)	1·03	·58 (7)

The bracketed figures are the actual number of claims made which allow some consideration of the significance of the rates.

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure.

‡ In claims per 100 person-years of exposure.

TABLE XLV.—*Sickness Rates (first 26 weeks) and Disablement Rates (after 26 weeks) for All Printers and for each Occupational Group for* 1921–25 *from ACCIDENTS.*

(*Cause Group* 13.)

	Age Group.*	All Printers.		Compositors.		Machine Printers.		Stereotypers and Electrotypers.		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
		Day rate.†	Claim rate ‡	Day rate †	Claim rate.‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡	Day rate.†	Claim rate.‡	Day rate †	Claim rate ‡	Day rate †	Claim rate ‡
Sickness	16–19	·37	1·97 (170)	·35	1·75 (69)	·40	2·09 (41)	·32	1·92 (9)	·46	2 17 (23)	·50	3·79 (14)	·26	1·41 (11)
	20–29	·34	1·13 (221)	·32	1·13 (89)	·31	1·16 (46)	·61	·74 (8)	·24	1·09 (31)	·59	1·15 (14)	·34	1 32 (32)
	30–39	·21	·79 (267)	·16	·70 (93)	·20	·78 (63)	·24	·89 (15)	·26	·78 (33)	·41	1·00 (24)	17	96 (38)
	40–49	·29	·95 (337)	·26	·90 (132)	·39	1·22 (105)	·27	81 (13)	·20	·71 (26)	·33	1·03 (28)	·22	·80 (33)
	50–59	·39	1·19 (332)	·32	1·13 (151)	·43	1·35 (72)	·43	1 19 (12)	·48	1·04 (28)	·65	1·56 (32)	39	1 10 (36)
	60–69	·46	1·37 (156)	·39	1·27 (78)	·74	1 56 (24)	·30	·85 (3)	·22	·79 (11)	1·15	2·59 (19)	·38	1·72 (21)
Disablement	16–19	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —
	20–29	·05	·06 (11)	·02	·04 (3)	·08	·05 (2)	·25	·37 (4)	—	— —	·11	·08 (1)	—	— (1)
	30–39	·05	·04 (14)	01	·02 (2)	·09	·07 (6)	—	— —	·15	·12 (5)	·03	·04 (1)	—	— —
	40–49	·05	·05 (17)	·01	·02 (3)	·02	·07 (6)	—	— —	·39	·14 (5)	·03	·07 (2)	·01	·02 (1)
	50–59	·09	·07 (19)	·04	·04 (5)	·28	·13 (7)	·08	·10 (1)	·03	·04 (1)	·01	10 (2)	07	·09 (3)
	60–69	·09	·12 (14)	·14	·11 (7)	·14	·33 (5)	—	— —	—	— —	·02	27 (2)	—	— —

The bracketed figures are the actual number of claims made which allow some consideration of the significance of the rates.

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure

‡ In claims per 100 person-years of exposure.

TABLE XLVI.—*Sickness Rates (first* 26 *weeks) and Disablement Rates (after* 26 *weeks) for All Printers and for each Occupational Group for* 1921–25 *from GOUT.*

(*Cause Group* 14.)

	Age Group.*	All Printers.		Compositors		Machine Printers		Stereotypers and Electrotypers.		Bookbinders and Rulers.		Warehousemen and Cutters		Lithographic Printers.	
		Day rate.†	Claim rate ‡	Day rate †	Claim rate ‡	Day rate.†	Claim rate ‡	Day rate.†	Claim rate ‡	Day rate †	Claim rate ‡	Day rate †	Claim rate.‡	Day rate †	Claim rate ‡
Sickness	16–19	—	— (1)	—	— —	—	— —	—	— —	·02	·09 (1)	—	— —	—	— —
	20–29	—	— (1)	·01	·01 (1)	—	— —	—	— —	—	— —	—	— —	—	— —
	30–39	·01	·07 (25)	—	— (3)	·03	21 (17)	·07	·24 (4)	—	— —	—	— (1)	—	— —
	40–49	·07	·43 (152)	·05	·32 (46)	·06	·43 (37)	·21	1·37 (22)	·02	·14 (5)	·33	1·40 (38)	·02	·10 (4)
	50–59	·19	1·09 (304)	·12	·83 (111)	·28	1·65 (88)	·51	2·70 (27)	·11	85 (23)	·36	1 61 (33)	·14	67 (22)
	60–69	·27	1·00 (114)	·25	·94 (58)	·34	1·75 (27)	·57	1·70 (6)	·19	·79 (11)	·64	·82 (6)	·09	·49 (6)
Disablement	16–19	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —
	20–29	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —
	30–39	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —	—	— —
	40–49	—	— (7)	·01	·02 (3)	·01	·02 (2)	·01	·13 (2)	—	— —	—	— —	—	— —
	50–59	·01	07 (20)	—	— —	·05	·28 (15)	·07	·30 (3)	—	— —	—	— —	·03	06 (2)
	60–69	·29	·15 (17)	·44	·20 (12)	—	— —	—	— —	—	— (1)	·87	55 (4)	—	— —

The bracketed figures are the actual number of claims made which allow some consideration of the significance of the rates

* Age last birthday at beginning of year of exposure.

† In days per person-year of exposure.

‡ In claims per 100 person-years of exposure.

The results thus reached by examination of the *separate causes* of illness may now be related to the conclusions derived from the study of the incidence of *all forms* of sickness upon the various occupational groups. On p. 48 it was stated that "compositors start insured life with a very unfavourable morbidity experience; their position improves in the next age group, 20–24, and at 25–64 they suffer considerably less than other classes of printers with the exception of bookbinders." The unfavourable experience at ages 16–19 is derived, it has now been shown, from most forms of incapacity, the only definite exceptions being diseases of the skin and accidents.

Compared with all *other* printers in this age group, 16–19 years, it was found that they have only three-quarters of the incapacity experienced by other printers from skin diseases, and about four-fifths of the accidents. In all other cause groups their excess is distinct, in most cases for both amount of time lost and for number of claims. The relative height of their phthisis rate in this age group is conspicuous, while in disablement the excess becomes very high, since, at this period of life, the compositors supply virtually the whole of the long-period claims, either from tuberculosis or from diseases of the nervous system. Their position improves at ages 20–29 in comparison with other printers, except for phthisis, in which they still show a considerable excess. Their favourable experience in the mid-life period is due to a lighter incidence of nearly all diseases—influenza, phthisis, rheumatism, respiratory illnesses, diseases of the digestive system and of the skin, and for accidents. Diseases of the nervous system and from "other causes" do not show this defect but are on a par with the rates experienced by all printers throughout life.

Turning next to machine printers, the deductions made from the study of all forms of morbidity were (p. 48) "machine printers and warehousemen produce an unfavourable impression in these comparisons. For many years of their working life they experience considerably higher sickness rates than do others in the printing trade. They do not show the very high initial rate of the compositors and in late life again they begin to lose their position of disadvantage, but at, roughly, ages 25–59 for machine workers and at 25–54 for warehousemen, the rates are strikingly in excess of those shown by compositors and all printers."

Analysis by cause has shown that machine printers derive this unfavourable experience after age 30 from many causes. In influenza they have a small excess from ages 20–49, in phthisis a distinct one, from 30–59 for sickness and from 40–59 for disablement. After age 30 they show an excess of rheumatism while from respiratory diseases they have a high incidence throughout life. From age 30 to age 59 they are at a disadvantage from diseases of the digestive system, and after age 40 from diseases of the skin and from accidents. Nervous diseases show the same incidence as that for all printers, while " other causes " reveal no distinct differences. The phthisis experience of later life is a factor of importance. Their rates are for sickness :—Age 40–49, ·64 days and ·78 claims, against ·41 days and ·51 claims for all printers (including themselves) ; and age 50–59, ·58 days and ·67 claims, against ·29 days and ·38 claims for all printers. In disablement the corresponding rates are :—Machine printers, 1·16 days and ·67 claims ; all printers, 1·00 days, ·50 claims ; machine printers, 1·37 days, ·52 claims ; all printers, ·65 days ·31 claims.

It should be observed that this incidence is *not* shared by the other group of machine printers—those working on lithographic machines.* These operatives have a relatively light phthisis experience throughout life and show no such high rates from age 40 to age 59. On the other hand, they show an undue amount of suffering from influenza and some excess of nervous diseases. They do not in comparison with all printers reveal any other very material differences. In comparison with machine printers they suffer considerably more from influenza and diseases of the nervous system (in most age groups), but less from rheumatism, respiratory diseases, and, as a whole, from diseases of the digestive system and of the skin, and in later life from accidents, as well as the lower phthisis experience already noted.

Warehousemen, whose unfavourable position for all causes has just been recalled, derive their high rates for short-period sickness from several disease groups—rheumatism, respiratory diseases, diseases of the digestive system, and of the skin, and from accidents. For the last two groups they are at a pronounced disadvantage. In phthisis they have an exceptionally high rate in the age group 30–39 both for sickness and for disablement, and in this age group they also suffer unduly from influenza and from rheumatism. For influenza, circulatory diseases, nervous diseases and " other causes " as a whole, they show no consistent differences. In gout they show a higher incidence than all other groups, except the stereotypers. In their disablement experience the number of claims is very small and their rates fluctuate in somewhat random fashion.

Referring again to p. 48, it is stated that bookbinders and rulers " show very low sickness rates, except that their duration per claim is high, and yet compared with compositors, or with all printers, they show an excess of disablement." These favourable sickness rates are apparent in several of the separate cause groups—in influenza, in rheumatism, in respiratory diseases and diseases of the digestive system, in diseases of the skin, and in " other causes." Small or inconsistent differences only are apparent in diseases of the naso-pharyngeal, circulatory and nervous systems and in accidents. Their high disablement experience at ages 20–29 (*see* Table XV) is due to a heavy incidence of phthisis and nervous diseases in this particular age group From age 30–39 no such disadvantage is found, but it again appears for ages 40–49, when both the phthisis rate and the nervous diseases rate are heavily in excess of the similar rates for all printers—phthisis, 1·65 days and ·74 claims against 1·00 days and ·50 claims for all printers ; nervous diseases, 2·20 days and ·80 claims against 1·07 days and ·43 claims for all printers. These two cause groups supply the explanation of the high disability rate of bookbinders, but why they bear so hardly at these particular ages, 20–29 and 40–49, and not in the intervening group, is not clear. In addition, except for phthisis at age 20–29, the difference is not apparent in short-period sickness. Probably the experience is too small to prevent random fluctuations being present and these particular rates are only chance fluctuations.

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* It must be recalled that lithographic printers' assistants could not be separated from the group entitled " machine printers," so that they are incorporated with that group and *not* with the lithographic printers.

Finally, there remain the stereotypers, of whom it was previously suggested (p. 48) that " they make more claims than all printers and more than compositors, but their claims are of shorter duration." The apparent random differences found for all causes of sickness are naturally accentuated in this study of individual causes. The rates move up and down and give no consistent answer for such diseases as those of the nervous system, of the skin, for " other causes," and accidents. Diseases of the digestive system are high in late life, and respiratory diseases are high after 30 years of age. Naso-pharyngeal diseases are, on the other hand, distinctly in excess up to age 40. The phthisis experience is very favourable with the exception of one age group, 40–49, when the disablement rate is abnormal, but this is based only on 13 claims. There is evidently a high incidence of rheumatism and gout after age 40 (in short-period sickness). These various differences may very well have no significant meaning as the exposed to risk was very small in number.

Summarising these conclusions broadly, it may be stated that the initial disadvantage observed at ages 16–19 for all printers is very apparent for nearly all forms of diseases amongst compositors, and that the latter are nearly entirely responsible for the pronounced tuberculosis rate in this age group. In later life, compositors and bookbinders have less sickness than other groups of printers, their advantage being extended to most groups of diseases, but the unfavourable phthisis experience of the compositors extends up to age 30 and reappears at ages 60–69. The high incidence of long-period incapacity amongst bookbinders is derived from this cause and from diseases of the nervous system, but appears only in age groups 20–29 and 40–49, and not in the intervening group. In view of the small number exposed to risk these rates may not be significant.

The greater amount of illness endured by machine printers and by warehousemen is traceable to a general inferiority at the older ages. Diseases of the nervous system and from " other causes " show least departure from the norm for all printers, but in nearly all other cause-groups these operatives show to disadvantage. Phthisis is distinctly high for machine printers of age 40–59, and for warehousemen of the previous age group, 30–39. The other machine printers, however, the lithographic printers (excluding their assistants) do not show a similar phthisis incidence but have, in comparison, a very favourable experience, both for this and for many other causes of sickness. On the other hand, they have some excess of nervous diseases, and of influenza. Stereotypers and electrotypers reveal no excess of phthisis and their most pronounced variation from the rates for all printers seems to be in their susceptibility to rheumatism and gout.

COMPARISON OF THE SICKNESS AND DISABLEMENT RATES OF WORKERS IN LONDON NEWSPAPER PRINTING OFFICES WITH THOSE OF WORKERS IN LONDON GENERAL PRINTING OFFICES.

At the request of the Newspaper Proprietors' Association of London, an attempt has been made to compare the incidence of morbidity in newspaper printing offices with that experienced in general printing offices. The difficulties involved are at once apparent. The two classes of workers are not distinct. Newspaper workers are largely recruited from operatives who have passed some part of their working life in general printing works, and there is a certain amount of ebb and flow from one branch of the industry to the other. This makes it difficult to place some workers definitely in either category over a five year period. For a part of the time they may have worked under one environment, and for a part of the time under the other. To obtain any absolutely accurate exposure to risk would be impossible within the limits of this inquiry. An operative has had to be classed as a newspaper worker if he was, during 1921–25, *mainly* in a newspaper office, and as a general printer if he was *mainly* in a general printing office. This is, however, only a minor imperfection in the data compared with the possibility, and probability, of one class being " select." Newspaper work is well paid work and in competition it is very possibly secured by the fittest mentally and physically. In addition, it is largely night work and high-speed work. The less fit and the less strong may feel it to be beyond them and remain in general printing. It may be too, that those who enter newspaper offices and become incapacitated by some major form of illness tend to drift back into the ranks of general printers to some less onerous work. All these factors would give the newspaper workers a lower sickness incidence *quite irrespective of the environmental conditions under which they work.*

How much these factors are operative is a question which cannot be answered. Only the possibility of their presence must be noted carefully. If they are operative to any appreciable extent, comparison of the morbidity rates between the two classes is entirely vitiated. The relative position of the rates is then mainly a function of the strength of the original selective force and of the intensity with which the incapacitated are eliminated from the newspaper offices.

In Table XLVII are given the standardised rates for all ages for newspaper workers and "general printers" of three occupational types—compositors, machine printers, and stereotypers. The exposed to risk are too few in number to allow age rates to be discussed and, indeed, for the disablement experience, they are even too few in number for all ages. In short-period sickness (first 26 weeks) the newspaper workers have higher rates for two occupational classes—compositors and stereotypers. Machine printers, on the other hand, have a more unfavourable experience in general printing offices. In disablement the stereotypers still show higher rates amongst the newspaper operatives, but in view of the small size of the exposed to risk this difference cannot possibly be taken as statistically significant. Compositors and machine printers working in newspaper offices have only just over half of the long-period incapacity of "general printers." The causes mainly responsible for this excess of disablement amongst "general printers" are, as would be expected, the main causes of all disablement in this experience, phthisis and diseases of the nervous system, while for compositors diseases of the

TABLE XLVII.—*Sickness and Disablement Rates (all Ages, standardised) for Workers in London Newspaper Printing Offices compared with the Rates for Workers in General Printing Offices in London.*

Occupational Group.	Exposed to risk at all ages.		Rate in days per person-year.		Claim rate in claims per 100 person-years.	
Sickness.	News-Office.	General Office.	News-Office.	General Office.	News-Office.	General Office.
Compositors . .	2300·0	14195·0	6·4	5·2	22·1	17·0
Machine printers	4183·0	6038·0	6·5	7·2	20·6	23·4
Stereotypers and Electrotypers	1446·5	2116·5	5·8	4·8	22·9	20·4
Disablement.						
Compositors . .	2288·0	13781·0	4·02	7·33	2·01	2·92
Machine printers	4126·5	5820·0	3·04	5·60	1·98	3·24
Stereotypers and Electrotypers	1418·5	2014·5	3·93	2·71	2·59	2·11

circulatory system also play a part in producing the unfavourable rate.

Even if these differences are statistically significant, it is out of the question to draw any conclusions as to their origin for the environmental and selective factors cannot be measured in any such inquiry as this. In other words, it is impossible to draw any conclusions from this comparison, both because of the unknown intensity of these factors and because the differences in incidence of sickness and disablement shown between the two groups, newspaper workers and general printers, are not consistent in the three occupational divisions. A special and detailed inquiry would be necessary to obtain any true comparison of the two grades.

Comparison of each Occupational Group of Printers with the Selected Societies' Experience.

The main conclusions that have been reached by this survey are, in brief, that printers as a whole experience less incapacity (as measured by days lost) than the general insured population of the country—taking the Selected Societies' experience to be representative of the whole insured population, but that when printers are divided up into broad occupational groups distinct differences between these groups are revealed.

Questions that it will be of some interest to answer are as follows :—If compositors have more incapacity than other printers in early life, do they similarly have more incapacity than the general insured population, or is it only that other printers are *still more* advantageously placed than the general insured population ? Is the excess of morbidity that machine printers suffer in later life only an excess when compared with the relatively low rates of, e.g. compositors, or does it represent an unduly high experience in comparison with other employed and insured persons ?

To answer such questions, Tables XLVIII and XLIX have been prepared. They show the sickness and disablement rates for each of the occupational groups for the years of the Selected Societies' experience, 1921–23. The rates for the Selected Societies are given and compared with those of the various types of printers both as absolute values and in percentage form, the printers' rates being expressed as percentages of the Selected Societies' rates.

In short-period sickness the answers are clear. The high rate of the compositors at ages 16–19 *is* high in comparison with the rate of the general insured population, though the excess is only 8 per cent. or 4·77 days of sickness for compositors, against 4·41 days for the Selected Societies. Their advantage over the general insured population is distinct throughout the rest of life. Machine printers in comparison with *other printers* showed their excess of sickness after age 40. It is after this age therefore that their rates most nearly approach those for all workers. But their excess of short-period incapacity over other printers *is not* an excess in comparison with the Selected Societies, their rates at these ages being barely on a par with the Selected Societies' rates.

Stereotypers and electrotypers show a very slightly higher rate in the first age group, but afterwards in conjunction with bookbinders and rulers and lithographic printers, show less sickness than the Selected Societies—as, having shown less sickness than all printers, they were bound to do.

Warehousemen and cutters shared with machine printers an excess of sickness over all other printers, showing especially high rates at ages 25–29 and 35–39 (*vide* Tables XVI and XVII and Figs. 3 and 4). In these two age groups their rates also exceed those of the general insured population—by 16 and 14 per cent., but their relative excess at other ages *is not* an excess in comparison with other workers. The excess in these two age groups is based on a somewhat small experience and may be not statistically significant.

The answers given by the disablement figures cannot be so clear. It was shown in Table XXV that the disablement experience with an exposed to risk of the size here obtained fluctuates from year to year and a three-year experience is not long enough to give stable rates in such narrow age groups. (For instance, 1921 is an abnormally bad year for compositors, and makes most of their rates higher than those of the machine printers. This is probably only a random fluctuation.) The individual rates and percentages, therefore, must not have too much importance attached to them.

The excess, due to tuberculosis, of compositors' disability over other printers at ages 16–19, is most definitely an excess also over all other insured workers. The only other disproportionately high rate shown by these operatives is at ages 30–34 due to a random fluctuation previously discussed. Machine printers show an excess over the insured population also in this age group, but otherwise only between ages 45 and 54 do they ever approach closely the rates of this latter class. Stereotypers show a nearly uniform advantage. The excess of bookbinders in disablement experience over other printers is also an excess in the same age groups over all insured workers, while warehousemen and cutters also are for much of their life more incapacitated by long-period illnesses than are the normal insured population. The high rate of lithographic printers at ages 20–24 is high both in comparison with other printers and with all other kinds of workers.

The conclusions, thus, are that the high rate of the compositors at ages 16–19 is high not only in comparison with other printers, but is definitely in excess of the incidence found

TABLE XLVIII.—*The Sickness Rates (Days of Sickness per Person-year) at Ages for each of the Occupational Groups of Printers compared with the Selected Societies' experience,* 1921–23. *Absolute Rates and each Rate as a Percentage of the corresponding Rate for the Selected Societies.*

Age Group.	Selected Societies	Compositors		Machine Printers.		Stereotypers and Electrotypers.		Bookbinders and Rulers		Warehousemen and Cutters		Lithographic Printers	
	Days of Sickness.	Days of Sickness.	As percentage of Selected Societies' rate	Days of Sickness	As percentage of Selected Societies' rate.	Days of Sickness.	As percentage of Selected Societies' rate	Days of Sickness	As percentage of Selected Societies' rate	Days of Sickness	As percentage of Selected Societies' rate	Days of Sickness	As percentage of Selected Societies' rate
16–19 ..	4·41	4·77	108	3·74	85	4·49	102	3·84	87	3 96	90	3 67	83
20–24 ..	4·69	3·34	71	3·51	75	2·99	64	3·99	85	2 58	55	4 37	93
25–29 ..	4·69	3·46	74	3·73	80	2·84	61	2 79	59	5 43	116	2 51	54
30–34 ..	4·97	2·65	53	4·26	86	3·50	70	2·59	52	4·03	81	3·08	62
35–39 ..	5·25	3·14	60	4·06	77	3·39	65	3 68	70	5·97	114	3·57	68
40–44 ..	5·60	3·25	58	5·43	97	5·38	96	3·83	68	4·89	87	4·30	77
45–49 ..	6·30	4·40	70	6·29	100	4·72	75	3·88	62	5·18	82	4·14	66
50–54 ..	7·70	4·56	59	7·26	94	7·02	91	5·81	75	5·40	70	6·15	80
55–59 ..	9·73	5·84	60	9·08	93	8·74	90	7·07	73	7·71	79	6·02	62
60–64 ..	12·95	9·62	74	9·68	75	9·98	77	11·64	90	10·86	84	9·05	70

TABLE XLIX.—*The Disablement Rates (Days of Disablement per Person-year) at Ages for each of the Occupational Groups of Printers compared with the Selected Societies' experience,* 1921–23. *Absolute Rates and each Rate as a Percentage of the corresponding Rate for the Selected Societies.*

Age Group.	Selected Societies.	Compositors.		Machine Printers		Stereotypers and Electrotypers		Bookbinders and Rulers		Warehousemen and Cutters.		Lithographic Printers.	
	Days of Disablement.	Days of Disablement.	As percentage of Selected Societies' rate.	Days of Disablement	As percentage of Selected Societies' rate.	Days of Disablement	As percentage of Selected Societies' rate.	Days of Disablement	As percentage of Selected Societies' rate.	Days of Disablement.	As percentage of Selected Societies' rate	Days of Disablement	As percentage of Selected Societies' rate
16–19 ..	·63	1·53	243	·43	68	—	—	·24	38	·28	44	·59	94
20–24 ..	1·19	·73	61	·92	77	—	—	1·77	149	1·57	132	3·29	276
25–29 ..	1·75	1·67	95	·95	54	·66	38	2·43	139	5·74	328	1·05	60
30–34 ..	2·10	3·06	146	3·01	143	1·84	88	1·76	84	1·61	77	2·16	103
35–39 ..	2·73	2·33	85	1·80	66	2·21	81	2·16	79	4·14	152	1·09	40
40–44 ..	3·36	2·60	77	2·48	74	2·34	70	6·94	207	3·60	107	1·59	47
45–49 ..	4·27	2·87	67	4·07	95	5·42	127	5·13	120	4·05	95	3·08	72
50–54 .	5·53	3·07	56	5·80	105	5·00	90	3·82	69	8·18	148	4·21	76
55–59 ..	9·87	8·24	83	5·20	53	4·90	50	5·51	56	2·40	24	11·17	113
60–64 ..	17·78	15·68	88	10·42	59	14·73	83	22·12	124	8·02	45	22·48	126

in the whole insured population. On the other hand, the unfavourable position which machine printers occupy amongst the printing groups results from the exceptionally low incidence of morbidity in those other groups. The machine operatives' rates are at a high level in comparison with those of skilled operatives of their own class ; they are not high in comparison with the population skilled and unskilled, that forms the insured section of the community. Stereotypers have rates much on a par with all printers and therefore are in a more advantageous position as regards time lost from morbidity than are operatives outside the printing industry. Bookbinders and warehousemen show an excess of long-period incapacity, not only over their own class, but also over all insured classes. Lithographic printers have a high rate (from phthisis) in one age group, 20–24 (which is not improbably a random fluctuation), but otherwise have a lighter incidence of illness than other insured workers.

It should be observed that these conclusions are based only on *days* of sickness and disablement, and not on claims ; the latter owing to the difference in definition previously referred to (p. 17), cannot be utilised for comparison.

A FURTHER STUDY OF THE INCIDENCE OF TUBERCULOSIS AMONGST THE OCCUPATIONAL GROUPS OF PRINTERS.

The rates set out in Table XXXV relating to the incidence of tuberculosis amongst the occupational groups of printers gave rise to the following general conclusions—the compositors are responsible for the excessive incidence of this disease in the first years of employment, from age 16 to age 19. Their rate continues to be high in relation to some of the other groups during the following age group, 20–29, but during these years of life their adverse experience is not unique but is shared by bookbinders. In later life they have relatively low rates, until, at the close of insured life, at ages 60–69, they have again an unfavourable experience. In middle life at ages 30–39, warehousemen alone have conspicuously high rates ; they continue to suffer considerably from 40–49, but after that age have a lighter experience than most of the other groups. From ages 40–59 the machine workers have high rates ; in short-period sickness they occupy this position alone, but in disablement, in age group 40–49, high rates are contributed also by stereotypers, bookbinders and warehousemen. The machine printers' high disablement rate at ages 50–59 stands alone. Lithographic machine printers show a low incidence throughout life. (In view of the small number exposed to risk in some of the occupational groups, it is probable that some of these rates are not significant, *vide* Appendix.)

These rates are open to one objection applying especially to the disablement experience. It has been pointed out that the morbidity was analysed for each calendar year and then totalled for the five years, and that thus a claim lasting over five years is, in the total, counted as five claims. When the treatment concerns a disease like phthisis, which may last over considerable periods of time and gives rise (unless the exposed to risk is very large) to no very great number of claims, this method is not entirely satisfactory. For instance, in the age group 40–49 the stereotypers have very high rates from disablement—2·12 days and ·82 claims against the 1·00 days and ·50 claims of "all printers." These former rates, on the other hand, are based on only 13 claims. If two persons had been sick from phthisis for the whole of the five years, 1921–25, their ages falling within this age group for the whole of the period, these two persons would have supplied 10 out of the 13 claims and 10 years of the duration of incapacity. On the other hand, these 13 claims might represent 13 individual cases, each suffering a relatively shorter period. It is obviously, then, important to discuss the actual number of *cases* of tuberculosis within the age groups and occupational groups and not only this rather artificial conception of claims.*

The cases have been counted for each occupational group and *case-rates* are given in Table L. For age-grouping purposes that age (age last birthday) was taken at which, within 1921–25, the tubercular illness began (so that for the reason given in the footnote these rates cannot be compared with the claim-rates of Table XXXV, but only with one another). The rates are the number of cases divided by the number of person-years of exposure for sickness (as given in Table XXXI). This is an arbitrary procedure, since the exposed to risk and the number of cases are not absolutely related, the former taking into account the movement of a person during the five years from one age group into another, while the latter cannot do so. *Inter se*, however, the rates are quite comparable, which is the only material point.

Table L shows a high case rate amongst compositors in the first age group, a rate which is not approached by any other group except bookbinders and with them the number of cases is very small and hence unreliable. More stress too may be laid upon the compositors' rate, since in this age group it has been shown that they suffer unduly from nearly every cause of sickness. Similarly, the uniformly high incapacity rates of machine printers from most causes of sickness from age 40 to age 59 are clearly reflected in this table, their rates in both age groups being considerably higher than those of any other of the occupational types. Warehousemen contribute to the excess of this disease at ages 20–39 (these rates may not be significant).

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* The advantage of the claim method, of course, is that it allows each calendar year to be taken separately and the age grouping to be made distinct and without overlapping. A "case," on the other hand, may run over from one age group to another during the five years' exposure, so that treated as a unit it can only appear in one age group although it concerns two. In other words, it produces overlapping age groups.

The conclusion to which one is led by this further study of the phthisis incidence in conjunction with the results given by the previous tables, especially Table XXXV, is that the abnormal phthisis incidence in the printing industry cannot be traced to any one occupational division within the trade. On the other hand, at certain ages the incidence does seem to be derived from specific occupations, namely, at 16–29 and 60–69, from compositors; at 30–59 from machine printers; and at 20–39 from warehousemen. This last occupational group is a relatively small one in this inquiry and it is very possible that these high rates are not significant. It will be seen that they are based on a very few cases.

If the phthisis case rates for *all printers* given in Table L are in excess of similar rates for the general population—and the relative mortality rates set out in Table I scarcely allow of any other conclusion, the phthisis mortality of printers being in excess in every age group*—then in comparison with the general insured population, compositors and machine printers must have a very heavy incidence of phthisis in the age groups mentioned.

The other occupational groups are too small in number and the cases of phthisis too few to enable conclusions to be safely made. The figures for bookbinders and machine rulers perhaps suggest that they have, throughout life, rates that are roughly on a par with those for all printers.

If the mortality from tuberculosis in this experience from 1921–23 be compared with the similar mortality for the same years as shown by the Registrar-General in his report on Occupational Mortality, then the three groups—compositors, machine printers (including lithographic printers), and bookbinders—show nearly uniformly lower mortalities than those given by the Registrar-General. This is probably due to the fact that in the sickness sample the classification is by cause of incapacity and not by cause of death, and in periods of illness lasting less than three months only the *first* diagnosis was obtained—e.g. the first diagnosis may have been pleurisy, so that for sickness purposes the period was placed in the cause group relating to respiratory diseases, whereas the death certificate might place the death under tuberculosis. Similarly, with sudden deaths from haemorrhage no sickness might be recorded. On the other hand, it may be observed that the death-rates as shown in the Registrar-General's report bear out, certainly to some extent, the difference here shown between the two main groups of printers—the compositors and the machine printers. The death-rates per 1,000 from tuberculosis of these two types, as shown by the Registrar-General's figures, are (in broad age groups):—16–25, compositors 2·04, machine printers 1·29; 25–45, compositors 1·85, machine printers 1·65; 45–70, compositors 1·99, machine printers 2·31. The early disadvantage of the compositors and the later disadvantage of the machine printers is in evidence.

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* This assumes a high correlation between morbidity and mortality, a not unreasonable assumption for such a disease as phthisis.

TABLE L.—*The Incidence of Tuberculosis amongst the Occupational Groups of Printers. The number of Cases* of Tuberculosis per* 100 *Person-years of exposure to Sickness.*

Age Group.	All Printers.		Compositors.		Machine Printers.		Stereotypers and Electrotypers.		Bookbinders and Rulers.		Warehousemen and Cutters		Lithographic Printers.	
	Number of cases	Case rate.†	Number of cases.	Case rate.†	Number of cases.	Case rate.†	Number of cases	Case rate †	Number of cases	Case rate †	Number of cases	Case rate †	Number of cases.	Case rate †
16–19 ..	29	·34	18	·46	5	·25	—	—	4	·38	1	·27	1	·13
20–29 ..	63	·32	33	·42	9	·23	—	—	10	·35	6	·49	5	21
30–39 ..	112	·33	40	·30	33	·41	4	·24	12	·28	10	·42	13	·33
40–49 ..	133	·38	47	·32	48	·56	5	31	12	·33	6	·22	15	36
50–59 ..	82	·29	32	·24	29	·54	2	·20	7	·26	6	·29	6	·18
60–69 ..	14	·12	12	·20	1	·06	—	—	1	·07	—	—	—	—

* A case is here defined as a person suffering from tuberculosis during 1921 to 1925 quite irrespective of whether the illness resulted in one or more *claims* to benefit during that period.

† Per 100 person-years of exposure to sickness.

CONSIDERATION OF THE RESULTS OBTAINED.

This investigation of the sickness found amongst the various occupational types engaged in the printing industry has thus led to the conclusion that there are certain definite differences in existence amongst these groups. Some discussion of these variations in morbidity incidence is obviously required.

Perhaps the most distinct and most specific attribute of any of the groups is the excessive liability of compositors to incapacity in the first years of their employment, followed by a relatively low incidence for nearly all the rest of their working life. Such an effect might be introduced by two means (or by a combination of the two) :—

(1) The environment under which they work may be such as to produce an abnormal amount of sickness (abnormal in comparison with other printers and with the general insured population). The weaker amongst them, those who cannot continue under the conditions, would be eliminated by death. Those who remain acquire an immunity to such diseases as tuberculosis and also are the more physically fit. Hence, the lower rates in later life.

(2) The occupation may be one which attracts a certain percentage of weaklings. It is an intellectual occupation, demanding no great physical strength, and it is possible that the tubercular and those generally of low physique might regard it as a suitable métier for their capacities. Such persons again would be eliminated from the trade, not necessarily because of its environment, but because they are unfit to retain their health and work under any conditions.

A combination of the two assumptions is possible—the occupation attracts the physically weak and the environment is not suited to such a class. The evidence produced by the incidence of various types of sickness suggests that the environment with regard to the factor of massive infection does not play a predominating part ; for the compositors of ages 16–19 are not only greater sufferers from infectious diseases (such as those of the respiratory system), but also from such causes as rheumatism, diseases of the digestive system and of the nervous system. This suggests rather a generally low physique, though of course it does not preclude the operation of *other* environmental factors, or the factor of massive infection in cramped quarters as well.

Such evidence as is produced by this inquiry can only indicate existing differences and allow explanations of such differences to be formulated. To prove such explanations further investigation would be needed. In this case the lines of further investigation seem to be clear. Compositors, and other workers in the printing industry, are recruited as apprentices and serve as such for a number of years, their terms of work and wages being regulated by various agreements between the respective Trade Unions and the Employers' Organisations. If the composing room is attracting an undue proportion of persons who are physically weak it should be possible to prove this fact by a medical examination of apprentices at entry. Machine workers, it was seen, have relatively low rates of incapacity in the early years of insured life, so that these workers can be utilised as the " control " group. Is the high morbidity incidence amongst compositors aged 16–19 due to the recruitment of weaklings ? Is the low morbidity incidence amongst machine workers in the same age group due to the recruitment of a more physically select class ? These are the two questions to be answered, and a further inquiry by medical examination of apprentices *at entry* into the trade would, it is suggested, supply the answers. Examination would have to be made for such factors as height and weight, general physique, muscular development, signs of tuberculosis or tubercular tendencies, etc. If no difference between the two types were found the variations in environment would then need detailed consideration. Presuming equality of physique at entry, some evidence of the effect of the environmental factors would be obtained if the medical examinations could be continued over the apprenticeship period, being made periodically over the first few years of work and not only at entry. The tables relating to tuberculosis suggested that bookbinders may have a relatively high incidence in early life, so that such medical inquiry might well be extended to them also, or indeed to the whole industry.

If the recruitment is not at fault, investigation of the environmental effects could also proceed by comparison of the morbidity experience in specific printing offices, the conditions of which could be examined in detail.

Turning to the high rates (relative to those of the other groups in the industry) of the machine workers from age 30 to age 59. These do not lend themselves so easily to further investigation. Comparison of individual works would again seem to be the best line of approach. One factor of possible significance with regard to these workers is their somewhat higher incidence of incapacity when compared with the lithographic machine printers. The environmental differences between the two groups that might be responsible are :—

(1) Economic position—the lithographic machine workers are more highly paid since this group includes only machine printers and *not* the assistants, these latter being included with the letterpress machine printers and their assistants ;

(2) Absence of newspaper work—night work and very high speed work—amongst the lithographic group ;

(3) More healthy working conditions, e.g., access to light and air.

Further investigation of the differences between these two types of machine printers, both in working and living conditions, might prove fruitful.

The warehousemen, it was shown, had relatively high general incapacity rates for most of their life and high phthisis rates at ages 20–39. This, again, may be an economic question, but it must be remembered that though relative economic status may play some part in producing differential morbidity rates amongst the various printing groups, it should play little part in producing the high phthisis incidence in comparison with the general population. For as a whole the industry is to-day a relatively well-paid one. Again, an investigation of the individual works would seem to be necessary in conjunction with a study of the recruitment of warehousemen. This group, however, and those made up of the stereotypers and electrotypers, the bookbinders and rulers and the lithographic printers are all of relatively small dimensions and the differences in sickness incidence are not distinct enough to lead to any absolutely reliable conclusions. The most important branches, as measured by size, are naturally the compositors and the machine workers, and the major problems arising out of this statistical analysis are, it is suggested, the high incidence of morbidity amongst compositors in early insured life, ages 16–19, and the high incidence amongst machine printers in middle insured life, ages 30–59. It is to these that particular attention is drawn, especially with regard to the merits and methods of any further investigation.

SICKNESS INCIDENCE AMONGST WOMEN WORKERS IN THE PRINTING INDUSTRY.

According to the census of 1921 there were some 70,000 women of 12 years of age and over employed in the occupations printing, bookbinding and photography. Very few of these are in the Approved Societies attached to the Trade Unions and, in spite of the addition of a Society outside the industry but containing a proportion of printing workers, only some 3,200 individuals were recorded. Of these 2,583 related to single women (at 1.1.21), and the remainder to married women. They were confined to three main groups—bookbinding, warehouse and machine work. The number of females in the other occupational groups was quite negligible. The number of married women is far too small to be of any service, and they have, therefore, been neglected. The sickness and disablement incidence has been analysed for the single women, but again the numbers are too small to make such treatment at all satisfactory, especially as out of the 2,583 individuals the great majority were exposed only for a part of the five years study. 1,005 of them were entries, and 715 were exits. The particulars are given for each of the groups in Table LI.

TABLE LI.—*The Occupational Groups of Women Printers examined (single and widowed women only); the numbers exposed to risk in each, together with the numbers of entries and exits over the period of investigation,* 1921–25.

Occupational Group.	Total number of persons exposed to risk during 1921–25.	Entries during 1921–25	Exits during 1921–25
Bookbinders .. .	1,695	652	454
Warehouse workers .	395	139	115
Machine workers	493	214	146
All printers . ..	2,583	1,005	715

It will be seen that the bookbinding group predominates, and that in each of the three divisions the ratio of entries and exits to the total number exposed to risk is very high.

TABLE LII.—*Sickness (first* 26 *weeks) and Disablement (after* 26 *weeks) amongst all Women Printers (Single and Widowed) compared with that experienced by the Departmental Committee's Selected Societies, for the years* 1921–23.

Age group (age last birthday at beginning of year of exposure).	Person-years of exposure.	Total duration of incapacity in days.	Number of claims made.	Rate in days per person-year.		Women printers' rate as percentage of selected societies' rate.
				Women printers	Selected societies.	
Sickness.						
16–19	2,676·0	15,584	588	5·19	5·53	94
20–29	2,801·0	19,869	601	6·36	6·02	106
30–39	1,515·5	10,105	296	5·80	6·23	93
40–49	881·5	6,136	177	6·53	7·49	87
50–59	385·5	3,364	87	8·90	9·59	93
Disablement.						
16–19	1,328·0	1,470	14	0·92	0·98	94
20–29	2,656·0	9,551	63	2·81	3·36	84
30–39	1,467·5	10,897	46	8·22	5·60	147
40–49	859·0	9,189	48	12·11	7·14	170
50–59	376·5	5,626	25	11·75	11·97	98

In Table LII, the sickness and disablement rates for the years 1921–23, for all these women are compared with the rates given by the Selected Societies' experience. In sickness no very great difference is to be seen. Except in the age group 20–29 the female printers hold a slight advantage,—an advantage by no means so distinct as that of the male printers (as shown in Tables IV and XLVIII). Except in the first age group the males had only, roughly, three-quarters of the duration of sickness suffered by the general population in the selected societies. The women, on the other hand, have some 90 per cent. of the general population's incidence. In disablement the women are at a very pronounced disadvantage from ages 30–49, but owing to the smallness of the exposed to risk those figures are very unreliable and cannot be trusted. In the other three age groups, little difference is revealed.

Comparison of the occupational groups either for all causes of sickness or, *a fortiori*, for particular causes of sickness is not feasible. The numbers of warehouse and machine workers are too small to allow it. If the last two groups be combined the following rates are the result :—

Age group.	Days of sickness per person-year.		Claims per 100 person-years.	
	Bookbinders	Machine and Warehouse Workers	Bookbinders	Machine and Warehouse Workers.
16–19	6·06	5·40	23 01	20·12
20–29	7·12	7·04	21·78	20·91
30–39	5·58	8·53	18·50	21·29
40–49	6·65	7·98	18·29	26·04

(after age 50 there are only 43 person-years of exposure for machine and warehouse workers). The bookbinders are at a disadvantage in the first group, on a par from ages 20–29 and definitely superior after age 30. The higher rates of the machine and warehouse workers after age 30 was observed similarly for the males, but in their case the bookbinders had also a low incidence at ages 20–29, and not so relatively an unfavourable experience as is here shown in the first years of insured life. It has been pointed out, however, that the occupations within the group are not identical for the males and females, a factor which may prevent any exact parallelism of sickness incidence. The size of the experience is too small to allow any discussion of the incidence of phthisis.

SUMMARY.

(1) The occupational mortality returns for England and Wales reveal the fact that printers, although they compare favourably in their general death-rate with all occupied and retired males, suffer unduly from tuberculosis. Their death-rate from all causes lies in most age groups between three-quarters and nine-tenths of the rates for all males ; with respiratory tuberculosis, on the other hand, they are consistently in an unfavourable position, their death-rate from this cause exceeding that for all males throughout life, often by a very considerable amount. The occupational mortality returns suggest that this is true not only for the whole printing industry, but for the occupational divisions within the industry (pp. 2 to 8 and Tables I, IA and II).

(2) Various explanations of this peculiar incidence of tuberculosis have been propounded, e.g. exposure to lead dust, inadequate ventilation and cramped quarters, the recruitment of

persons of low physique. No solution of the problem has been reached and the size and importance of the industry—nearly a quarter of a million persons are employed in it—and its widespread distribution, seemed to be sufficient warrant for further investigation. The present inquiry, undertaken at the request of the Joint Industrial Council for the Printing and Allied Trades and of the Newspaper Proprietors' Association of London, is confined to an examination of the incidence of morbidity, both from tuberculosis and from all causes of disease, amongst the various occupational divisions of the industry (pp. 2 to 8).

(3) The data were secured from the records kept by Approved Societies for administering the provisions of the National Health Insurance Acts. The Societies confined to the printing industry were selected. These were nine in number and supplied records relating to, roughly, 36,000 males and (with the inclusion of a more " general " Society) 3,000 females. The years chosen for investigation were 1921–25 inclusive. The occupations analysed were as follows :—Compositors, machine printers (including lithographic printers' assistants), stereotypers and electrotypers, warehousemen and cutters, bookbinders and rulers, lithographic machine printers, lithographic artists, and journalists. The data relating to the last two groups were held to be unsatisfactory (these workers are not manual workers under the terms of the National Health Insurance Acts) and no uses have therefore been made of them (pp. 8 to 15 and Table III).

(4) The duration of incapacity suffered from all causes of illness by all printers during 1921–23 was compared with the experience of the Selected Societies for the same years (an experience analysed by the Government Departmental Actuarial Committee), the Selected Societies being taken to represent the general insured population. It was found that relative to their experience in later life the printers had high rates from sickness (first 26 weeks of incapacity) and from disablement (after first 26 weeks of incapacity) in the first years of insurance, i.e. at 16–19 years of age and that compared with the general insured population, they occupy their most unfavourable position in this age group. In later age groups they are for short-period incapacity at a distinct advantage throughout insured life, their rates of sickness being roughly only three-quarters of those for the insured population. For long-period incapacity this position of advantage is not reached till later in life—in the age group 35–39, after which age they have approximately only four-fifths of the disablement suffered by the insured population (pp. 16 to 21 and Tables IV and V).

(5) Comparing for all causes of diseases the occupational groups one with another for the years 1921–25 (number of days of sickness suffered, the number of claims made, the length of the claims made, and the number of operatives falling sick once or more than once in the period of survey) the general conclusion was reached that *Compositors* begin (and perhaps end) their

working life unfavourably as regards morbidity experience, but that for all the major portion of the time during which they are occupied they hold a position of distinct advantage in comparison with others in the printing trade. Their only rivals are the *Bookbinders and Rulers,* who have a still lower sickness incidence —though the claims that they make are of longer duration— and yet suffer considerably from disablement (long-period illness). *Machine Printers, and Warehousemen,* on the other hand, when compared with all printers, or with compositors, reveal a materially higher incidence of morbidity. For *Stereotypers and Electrotypers* and for *Lithographic Machine Printers,* the evidence is less definite, but the indication is that they do not share the advantages of the compositors, in the number of claims that they make, but that their claims are of short duration (pp. 21 to 59, Tables VI to XXIX, and Figs. 1 to 5).

(6) Analysing the incidence of particular groups of diseases amongst the various occupational divisions it was found that the initial disadvantage observed at ages 16–19 for all printers is largely derived from the high incidence of nearly all diseases at these ages amongst compositors, and that the latter are nearly entirely responsible for the pronounced tuberculosis rate in this age group. In later life compositors and bookbinders have lower rates than other groups of printers, their advantage being extended to most groups of diseases, but the unfavourable phthisis experience of the compositors extends up to age 30 and reappears at ages 60–69. The high incidence of long period incapacity amongst bookbinders is derived from this cause and from diseases of the nervous system. but appears only in age groups 20–29 and 40–49 and not in the intervening group, and in view of the small number here exposed to risk it is possible that these rates are not significant.

The greater amount of illness endured by machine printers and by warehousemen is traceable to a general inferiority at the older ages. Diseases of the nervous system and from "other causes" show least departure from the norm for all printers, but in nearly all other cause-groups these operatives show to disadvantage. Phthisis is distinctly high for machine printers of ages 40–59, and for warehousemen of the previous age group, 30–39. The other machine printers, however, the lithographic printers (excluding their assistants) do not show a similar phthisis incidence, but have, in comparison, a more favourable experience, both for this and for many other causes of sickness. On the other hand, they have some excess of nervous diseases and of influenza. Stereotypers and electrotypers reveal no excess of phthisis and their most pronounced variation from the rates for all printers is found in their susceptibility to rheumatism and gout (pp. 59 to 89 and Tables XXXI–XLVI).

(7) An attempt was made to compare the sickness incidence amongst newspaper workers with that amongst general printing workers, but, for reasons discussed in the text, no valid conclusion could be reached (pp. 89 to 91 and Table XLVII).

(8) Comparison of the amount of incapacity suffered by the occupational groups of printers during 1921–23 with the Selected Societies' experience leads to the conclusion that the high rate of the compositors at ages 16–19 is high not only in comparison with other printers, but is definitely in excess of the incidence found in the whole insured population. On the other hand, the unfavourable position which machine printers occupy amongst the printing groups results from the exceptionally low incidence of morbidity in those other groups. The machine operatives' rates are at a high level in comparison with those of skilled operatives of their own class; they are not high in comparison with the general population, skilled and unskilled, that forms the insured section of the community. Stereotypers have rates much on a par with all printers and therefore are in a more advantageous position as regards time lost from morbidity than are operatives outside the printing industry. Bookbinders and warehousemen in several age groups show an excess of long period incapacity, not only over their own class, but also over all insured classes. Lithographic printers have a high rate (from phthisis) in one age group, 20–24, but otherwise have a lighter incidence of illness than other insured workers. These conclusions are based only on *days* of illness and not on claims, the latter not being comparable owing to a difference in definition in this inquiry and the Selected Societies' experience (pp. 91 to 95 and Tables XLVII and XLVIII).

(9) Further study of the incidence of tuberculosis amongst the occupational groups gave rise to the statement that the abnormal incidence of phthisis in the printing industry is derived at least in part from compositors at the beginning and end of insured life, and from machine printers in late insured life. Warehousemen show an apparently high incidence at ages 30–39 and the rates of bookbinders and cutters are very similar to those for all printers throughout life. The figures for lithographic printers and stereotypers and electrotypers suggest a lighter incidence, but for all these latter groups the exposed to risk is so relatively small that definite conclusions cannot safely be drawn (pp. 95 to 98 and Table XLIX).

(10) Perhaps the most distinct and most specific attribute of any of the groups is the excessive liability of compositors to incapacity in the first years of their employment, followed by a relatively low incidence for nearly all the rest of their working life. Such an effect might be introduced by an unfavourable working environment or by recruitment of persons of low physique (or by both means). If the composing room is attracting an undue proportion of persons who are physically weak, it should be possible to prove this fact by a medical examination of apprentices.

The high rates of the machine workers at ages 30–59 might be further explored by the comparison of individual works and by a further study of the differences between these workers and lithographic printers whose incapacity experience was distinctly lower. It is suggested that these two factors (the high incidence of morbidity amongst compositors in early insured life, ages 16–19, and the high incidence amongst machine printers in middle insured life, ages 30–59), form the major problems, since these branches of the trade are easily the most important as measured by size and it is to these that particular attention is drawn (pp. 99 to 101).

(11) The study of sickness incidence amongst single and widowed women in the printing industry suggests that they hold a very slight advantage in amount of sickness experienced over the general insured population. Occupational comparisons and analysis by cause of sickness cannot be made as the exposed to risk are too few in number (pp. 101 to 103 and Tables LI and LII).

APPENDIX.

Throughout this report various differences in sickness rates found amongst the occupational groups have had to be discussed, and in some cases these rates are based upon relatively small numbers exposed to risk. It has been pointed out that such differences must be regarded with a considerable degree of caution, but it has not been thought wise to encumber the text with any elaborate statistical tests of their significance. In Table L, one such test has been used to measure the probability that the differences there found in the incidence of tuberculosis are significant. Pearson's ${\chi^2}_0$ test for measuring the existence of differential death rates was applied (Biometrika, 1915–17, XI, pp 159–184). This is a method for testing not any single character of a frequency distribution but the distributions as a whole, e.g , the death or sickness rates over a number of age groups. It shows whether the rates found in one population differ significantly, not individually but as a whole, from the rates found in a second population. In Table L the test was applied to the difference in rates found between compositors and machine printers. In this case no doubt at all exists as to the significance of the difference. The odds are nearly 2,500 to 1 against this difference in incidence having arisen by chance.

When machine printers are compared with lithographic machine printers the odds against the difference having arisen by chance are far smaller—about 7 to 1. (The conclusion reached in the report that these two groups probably differ significantly in their sickness experiences is, of course, not based only upon this table, but upon the differences found for other causes and all causes of sickness.)

Comparison by means of this test between the bookbinders and rulers and the warehousemen and cutters shows that, with such small groups as these, the differences here found may very easily have arisen by chance. Differences of this magnitude found in the smaller occupational groups, in particular sickness cause groups must not, therefore, have any importance attached to them.

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Greenwood, M., and Newbold, E. M. (1923) : On the Estimation of Metabolism from Determinations of Carbon Dioxide Production and on the Estimation of External Work from the Respiratory Metabolism.—*J. Hyg.*, **21,** 4.

Hambly, W. D., and McSwiney, B. A. (1922) : The U-tube Manometer Test with relation to Muscular Exercise.—*Proc. Physiol. Soc.*, Oct. 21, 1922.

Hambly, W. D., Pembrey, M. S., and Warner, E. C. (1925) : The Physical Fitness of Men assessed by various Methods.—*Guy's Hosp. Rep.*, Oct., 1925.

Hewitt, E. M., and Bedale, E. M. (1923) : A Study of the Comparative Physiological Costs of Different Methods of Weight Carrying by Women.—*Ann Rep. of the Chief Inspector of Factories for* 1922

Hill, A. V. (1927) : *Muscular Movement in Man.* New York.

Hill, A. V. (1927) : *Living Machinery.* London.

HILL, A. V., LONG, C. N. H, and LUPTON, H (1924): Muscular Exercise, Lactic Acid and the Supply and Utilisation of Oxygen.—*Proc. Roy. Soc.*, B **96,** 438; **97,** 84; **97,** 155.

HILL, A. V, and LUPTON, H. (1923): Muscular Exercise, Lactic Acid, and the Supply and Utilisation of Oxygen.—*Quart. J. Med.*, **16,** 62.

HILL, L., VERNON, H. M, and HARGOOD-ASH, D. (1922): The Kata-Thermometer as a Measure of Ventilation.—*Proc. Roy. Soc.*, B **93,** 198.

JAMES, H. E O., and THOULESS, R. H (1926): A Note on the Effect of Polarisation in Psycho-Galvanic Experiments.—*Brit J. Psych*, **17,** 1.

LUPTON, H (1922): Relation between External Work and Time Occupied in a Single Muscular Contraction—*J. Physiol.*, **57,** 1 & 2.

LUPTON, H. (1923): Exercise and Oxygen.—*Med. School Gaz.*, **2,** 3.

LUPTON, H (1923): An Analysis of the Effects of Speed on the Mechanical Efficiency of Human Muscular Movement.—*J. Physiol.*, **57,** 6

MUSCIO, B. (1920): Fluctuations in Mental Efficiency.—*Brit. J. Psych.*, **10,** 4.

MUSCIO, B. (1921): Is a Fatigue Test Possible ?—*Brit. J Psych.*, **12,** 1

MUSCIO, B. (1921): Feeling Tone in Industry.—*Brit. J. Psych*, **12,** 2.

MUSCIO, B (1922): Motor Capacity with Special Reference to Vocational Guidance.—*Brit. J. Psych.*, **13,** 2.

MUSCIO, B., and SOWTON, S. M. (1923): Vocational Tests and Typewriting—*Brit J. Psych.*, **13,** 4

NEWBOLD, E. M. (1923): Note on Dr. Burnside's Paper on Errors of Observation.—*Biometrika*, **15,** 3 & 4.

PEAR, T. H. (1927): Repetitive Work.—*Dictionary of Industrial Administration.*

PEAR, T. H. (1927): Work, Temperament and Fatigue.—*Rep. Internal Ass. for Study of Relations and Conditions in Industry.* (Baveno), 1927.

PEAR, T. H., (1927): Recent Studies of Skilled Performance with reference to Transfer of Training.—*Nature*, 18th Jan.

PEMBREY, M. S, and OTHERS (1922): Tests for Physical Fitness—Part I.—*Guy's Hospital Reports*, Oct., 1921. Part II.—*Ibid*, Oct., 1922.

RUSHER, E A. (1922): The Statistics of Industrial Morbidity in Great Britain.—*J. Roy. Stat. Soc.*, **85,** 1.

SARGENT, R M. (1926): The Relation between Oxygen Requirement and Speed in Running.—*Proc. Rov Soc. B.*, Vol **100,** 1926

SMITH, MAY (1923): Practical Problems of Industrial Life—*Ind. Welfare*, **5,** 58.

SMITH, MAY (1923): The Laundry Trade.—*Laundry Record*, **33,** 388.

SMITH, MAY (1926): Industrial Psychology.—*Article in Encyclopædia Britannica* (*XIIth Edition*).

STURT, M. (1922): A Comparison of Speed with Accuracy in the Learning Process.—*Brit. J. Psych.*, **12,** 3

VERNON, H. M. (1921): The Influence of Atmospheric Conditions on Industrial Efficiency.—*J. State Med.*, **29,** 353

VERNON, H. M. (1921): The Influence of Fatigue on Health and Longevity.—*J. Ind. Hyg.*, **3,** 3

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VERNON, H. M. (1923): A Note on the Causes of Output Limitation.—*J. Nat. Inst. Ind. Psych.*, **1,** 5

VERNON, H. M. (1923): Atmospheric Conditions in Potters' Shops and the Efficiency of Various Types of Drying Stoves—*Trans. Ceramic Soc.*, 22, p. 70.

Vernon, H. M. (1923): The Causation of Industrial Accidents.—*J. Ind. Hyg.*, **5**, 1.

Vernon, H. M., and Bedford, T. (1924): The Influence of Short Time on Speed of Production.—*J. Nat. Inst. Ind. Psych.*, **2**, 155.

Vernon, H. M. (1925): Can Laboratory Experiments on Output throw Light on Problems of Industrial Fatigue?—*Brit. J. Psych.*, **15**, 4.

Vernon, H. M. (1925): The Kata-Thermometer as an Indicator of Radiant Heat.—*J. Nat. Inst Ind. Psych.*, **2**, 198.

Vernon, H. M. (1925): The Work of the Tin-Plate Doubler.—*J. Nat. Inst. Ind. Psych.*, **2**, 373.

Vernon, H. M. (1926): Is Effective Temperature or Cooling Power the Better Index of Comfort?—*J. Ind. Hyg.*, **8**, 392.

Vernon, H. M. (1927): The Elimination of Fatigue caused by Extremes of Temperature, Humidity and Dust—*Rep. Internat. Ass. for Study of Human Relations and Conditions in Industry.* (Baveno), 1927.

Vernon, H. M. (1927): Ventilation in relation to Health.—*J. State Med.*, **34**, 683.

Vernon, H. M. (1927): The Wet Kata-thermometer as an Index of the Suitability of Atmospheric Conditions for Heavy Work.—*J. Indust Hyg.*, **9**, 287.

Vernon, H. M., and others (1926): Methods of Investigating Ventilation and its Effects.—*Med. Res. Council Spec. Rep. Series No* 100.

Vernon, H. M., and Bedford, T. (1927): The Ventilation and Heating of Factories.—*J. Indust. Hyg.*, **9**, 51.

Vernon, H. M., and Vernon, M. D. (1927): The Physical and Physiological Effects of Radiant Heating by the Panel System.—*Proc. Physiol. Soc., J. Physiol.*, **64**, 1.

Vernon, M. D. (1926): On Certain Effects of Long Spells of Repetitive Work.—*Brit. J. Psych.*, **16**, 3.

Warner, E. C., and Hambly, W. D. (1925): An Investigation into the Physiological Basis of the U-tube Manometer Test.—*Guy's Hosp. Rep.*, July, 1925.

Weston, H. C. (1927): The Relation between Illumination and Efficiency in Fine Processes, with special reference to the Lighting of Printing Works.—*Illum. Engineer*, **20**, 221.

Weston, H. C. (1927): Light and Vision in Industry.—*Rep. Internat. Ass. for Study of Human Relations and Conditions in Industry* (Baveno), 1927.

Wilson, D. R. (1921): Some Effects of Environment on Efficiency and Safety.—*J. Roy. San. Inst.*, **42**, 3.

Wilson, D. R. (1921): The Work of the Industrial Fatigue Research Board, and its Applications to Industry.—*J. Roy. Soc. Arts*, **70**, 3660.

Wilson, D. R. (1923): On Some Recent Contributions to the Study of Industrial Fatigue.—*J. Roy. Stat. Soc.*, **86**, 4.

Wilson, D. R. (1923): International Co-operation in the Study of Industrial Psychology and Physiology.—*International Labour Office, Studies and Reports, Sec. F., No.* 9.

Wilson, D. R. (1924): Some Observations on Industrial Lighting.—*J. Ind. Hyg.*, **5**, 10.

Wilson, D. R. (1924): Man in Relation to Production.—*First World-Power Conference*, **412.**

Wyatt, S. (1925): The Effect of Atmospheric Conditions on Health and Efficiency (with special reference to the Cotton Industry).—*J. Ind. Hyg.*, **7**, 7.

Wyatt, S. (1927): An Experimental Study of a Repetitive Process.—*Brit. J. Psych.*, **17**, 3.

Wyatt, S. (1927): Machine Speeds and Output.—*J. Nat. Inst. Indust. Psych.*, **3**, 8.

Wyatt, S., and Weston, H. C. (1920): A Fatigue Test under Industrial Conditions.—*Brit. J. Psych.*, **10**, 4.

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Report No. 55.

MEDICAL RESEARCH COUNCIL.

INDUSTRIAL HEALTH RESEARCH BOARD.

(FORMERLY THE INDUSTRIAL FATIGUE RESEARCH BOARD.)

A Study of Personal Qualities in Accident Proneness and Proficiency.

By Eric Farmer & E. G. Chambers.

LONDON:
Printed and Published by His Majesty's Stationery Office, and to be
purchased at any of the addresses shown overleaf.

1929

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MEDICAL RESEARCH COUNCIL.

INDUSTRIAL
HEALTH RESEARCH BOARD.
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REPORT No. 55.

A Study of Personal Qualities in Accident Proneness and Proficiency.

By Eric Farmer & E. G. Chambers.

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PREFACE.

For several years the Industrial Health Research Board have given part of their resources to the investigation of accident causation from its personal rather than from its mechanical aspect This investigation has proceeded mainly in two stages, first a general exploration of the field through the statistical analysis of accident records, and secondly the study of the influence both of the worker's environment and of his personality upon his liability to sustain accidents.

On the statistical side, two investigations have been undertaken for the Board. The first of these was conducted in 1919 by Greenwood and Woods,* the material used being a large number of records relating to accidents incurred in munition factories during the War The aim of the inquiry was to test the validity of certain hypotheses relating to accident incidence.

In the first place, it was assumed that all workers start equal in respect of liability, and that accidents are really accidents in the strict sense of the word and due *only* to chance. According to a second hypothesis, all workers again start equal, but the incurring of any accident modifies the chance of sustaining a second accident. Another hypothesis again assumes that all persons do not start equal, but that under equal exposure to risk some are inherently more liable to suffer casualties than others; in other words, that individuals vary in their susceptibility to accident.

These three alternative hypotheses were tested by statistical methods of some complexity, and the conclusion drawn from this investigation was that the third hypothesis is the correct one, whilst no indication could be found of the validity of the other two. This result in itself is perhaps what would be expected, but a further fact of some significance emerged, the bulk of accidents were found to occur among a comparatively limited number of workers.

This early work by Greenwood and Woods was repeated on a larger scale by Newbold in 1926, by the statistical analysis of some 16,000 records specially kept for the purpose by a number of large firms in England.† A similar procedure was adopted, with slightly modified statistical formulae. The results of the second investigation completely confirmed the original findings of Greenwood and Woods, in showing, not only that there was unequal susceptibility amongst workers, but that the specially susceptible workers were comparatively few in number, or, in the words of the Report itself, "that the average number of accidents in any homogeneous group was much influenced by a comparatively small number of workers."

The practical importance of these two findings hardly needs emphasis. The former of them shows that there is a definite

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* I.F.R.B Report No. 4. † I F.R B. Report No 34.

(34997) Wt 18364/569/1461 1000 10/29 Harrow G.25 B scope for further research on the subject with a view to determining the psycho-physiological factors in this special susceptibility with the object of being able eventually to ensure that susceptible persons are placed in appropriately safe occupations The second conclusion is perhaps even more important as suggesting that if suitable tests for accident susceptibility could be devised, their practical application would be comparatively easy and would result, without any great administrative disturbance, in the diminution of accidents at a given place of work

The ground having been cleared to some extent by means of these statistical inquiries, the attention of the Board has more recently been directed first to the investigation of the effects of environmental and other conditions on accident rates, and secondly to the study of the factors underlying individual proneness to accident.

The former of these may be regarded as including all extrinsic conditions not inherent in the individual, but imposed upon him by force of circumstances

Considering first the physical environment of the worker, Vernon and others have shown that atmospheric conditions appear to have an appreciable influence on accident rate. Osborne and Vernon, for instance, by installing recording thermographs in two large munition factories during the War, were able to ascertain the approximate temperatures at which the accidents recorded in the ambulance room were incurred over periods of 10 to 12 months.* The results obtained clearly suggested that there is an optimum temperature of about 67·5°F. at which accident incidence is at a minimum, and that it increases as the temperature rises above or falls below that point As the authors point out, however, the best temperature for accident prevention is not necessarily the most suitable one for working efficiency, and there is little doubt that a temperature of 67°F. is too high for the attainment of maximum efficiency if the work is at all active.

Further light is thrown on this subject through another investigation by Vernon and Bedford on the relation of atmospheric conditions to accidents incurred in certain collieries.† The results show that as the temperature of the seam rose (or the kata cooling powers fell), the accident frequencies of the colliers and trammers, who work at or near the coal face, tended to increase, whilst the accident frequencies of the haulage men and other workers, who work in the airways where the temperatures are lower, remained practically constant throughout.

These preliminary conclusions have recently been confirmed through another investigation by Vernon and Bedford relating to the causes of absenteeism in a group of collieries employing 23,000 miners.‡ In this inquiry, it was again shown that accident frequency was closely associated with temperature, but that this association was limited to the less severe type of accident, the more serious accidents showing no such relationship, for whereas accidents involving absence of less than 10 days increased fivefold within a temperature range of 60°—80°F, the major accidents were slightly less numerous at the highest temperatures than at the lowest, whilst the less severe accidents occupied an intermediate place. This differentiation between major and minor accidents is attributed by the authors to the more ready tendency on the part of the men working at high temperatures to report small accidents.

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* I F.R.B. Report No. 19. † I.F R.B. Report No. 39.
‡ I F R B. Report No. 51.

Another factor influencing accidents appears to be air velocity, for the accidents incurred by underground men other than coal-face workers increased steadily at all velocities from 70 feet per minute upwards, and at a velocity of 264 feet they were 68 per cent. more numerous.

Several other factors influencing accidents have also received some attention. Thus, Osborne and Vernon investigated the parts played by speed of production and fatigue respectively, through the analysis of more than 50,000 accidents incurred in munition factories working day and night, in which the variations in output throughout the period were measured simultaneously with the variations in accident incidence Their main conclusions may be summarised as follows :—

(*a*) In the case of the day shift, a strong qualitative resemblance exists between the rate of output curves and the accident curves, thus suggesting that varying speed of production is responsible for the variations in accident incidence rather than fatigue.

(*b*) That fatigue may be an important contributing cause, however, is shown by the fact that during a period when a 12 hour day (75 hour week) was being worked the accidents incurred by women were two-and-a-half times more numerous than in the subsequent period when the daily hours were reduced to 10

(*c*) In addition to speed of production and fatigue, an important part is played by psychical influences, such as alertness and attention. This conclusion is based on a comparison between the accident incidence on the day shift and on the night shift. Whereas in the former the accident curve follows the output curve very closely, in the latter it is widely different Here the accident rate is at a maximum at the beginning, then falls sharply and finally sinks to less than half the original value. Further, the total accident rate is lower by an average of 16 per cent. with no decrease in output.

The authors ascribe these differences to psychical influences, assuming that the night workers started work in a careless and excited state and gradually settled down to a calmer mental state than the day workers.

The first of these conclusions received some confirmation from laboratory experiments conducted by Muscio in 1921,* in which two tests of muscular precision involving eye-hand co-ordination were applied to subjects, the speed of performance of these tests being varied to a known extent by means of a metronome. These experiments tended to show that accuracy of movement, while constant throughout spells up to 2½ hours in length when the speed of performance is constant, rapidly decreases when the speed of performance is increased. The conclusion suggested by these results is that variations in accident incidence is due to rate of work, rather than to fatigue.

The study of the personal factors in accident causation was begun for the Board by Farmer and Chambers in 1926.† In this research selected psychological tests were applied to six groups of workers (six hundred and fifty subjects in all) engaged in different occupations, and the results of the tests compared with the accident records of the subjects examined. The method of comparison was first to express each individual's accident rate as a percentage of the mean accident rate of the whole group; for each test the group was next divided into two sub-groups, consisting of those whose scores were above and below the average score for the whole group, finally the average rates (expressed as a percentage) of these two groups were compared.

The results suggest that in most of the tests those with the better scores tended to have the fewer accidents, though in most instances the differences shown were not significant in the statistical sense. When, however, the three tests (reaction, dotting and pursuit meter) which yielded significant differences were combined (after suitable weighting) a difference of 48 per cent. in the accident rates between those who "passed" and "failed" in the combined tests was disclosed.

Investigation on this side of accident causation has recently been extended by Farmer and Chambers to larger numbers of subjects, consisting of 1,800 apprentices in the workshops of certain Naval and Royal Air Force Establishments, the results of which are described in the present report. In this a similar procedure has been adopted, but the larger scope of the inquiry has admitted of the use of the correlation method in the statistical analysis of the results. The conclusions of the earlier report are confirmed in the case of the four groups of the Dockyard Apprentices, since the same three tests yielded significant correlation coefficients between the scores and accident rates, whereas the coefficients for nearly all of the other tests were low, inconsistent and non-significant.

According to the authors, then, there is now reason to believe that the tests referred to (named by them aesthetokinetic) do actually measure some factor in accident proneness, a supposition supported by the fact that they inter-correlate significantly amongst themselves.

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* I.F.R.B. Report No. 19.

† I.F.R.B. Report No. 38.

As an illustration of the eventual practical possibilities of tests for selective purposes when further knowledge has been gained, it may be pointed out that in these groups the accident rate of the worst 25 per cent. was about 2½ times as great as that of the remaining 75 per cent.

As the authors themselves point out, the correlation coefficients between the tests and accident rate were for the most part small, thus suggesting that accident proneness is dependent on many dominant factors and not on a single predominant one, and affording no evidence that the tests measure the most important of these. This can only be determined by further experiment.

Several other matters of theoretical interest have emerged from this investigation. Some evidence, for instance, is adduced to show that industrial proficiency is associated with low accident rate, and that the common factors in this association are to some extent measured by the tests

Then again, attention may be directed to the Appendices to this Report, which consist of a series of short notes on miscellaneous points disclosed as bye-products to the main investigation, such as the increase in the degree of association between certain tests and accidents with increasing length of exposure, and the high inter-correlation between the different passing out records of the Royal Air Force Apprentices.

Aug., 1929.

A STUDY OF PERSONAL QUALITIES IN ACCIDENT PRONENESS AND PROFICIENCY,

BY

ERIC FARMER, M.A., AND E. G. CHAMBERS, M.A

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General Introduction.

In 1926 the Industrial Fatigue Research Board published a report* in which an account was given of certain experiments that had been carried out to examine the possibility of discovering by means of psychological tests individuals who were specially prone to sustain industrial accidents. The work described in that report was the outcome of the statistical investigations of Greenwood and Woods, Yule and Newbold,† which showed that accident distribution was not a purely chance distribution, but that there were certain individuals in any group who were more liable to sustain accidents under equal conditions of exposure than their fellow workers, and also that the bulk of the accidents in any group of workers are sustained by relatively few individuals. The conclusions arrived at in the report were of a tentative nature, but the fact that those persons whose performance was better than the average in a certain group of sensori-motor tests—which were called aesthetokinetic tests—also had an accident rate lower than the average, showed that inequality in accident liability was in part due to individual measurable differences. The purpose of the report was to illustrate a new method of approaching the study of accident causation and more clearly to define certain associated problems. The investigation described in the present report is a direct continuation of the previous one, and was carried out with the object of re-testing the earlier conclusions and examining more closely certain problems then mentioned as needing special study.

In order to present the results of the investigation as clearly as possible the following procedure has been adopted. In this Introduction a general indication of the results obtained is given without any attempts at proof. In Part I the tests used and the groups tested are described. In Part II certain theoretical considerations are advanced as to the nature of intercorrelation and the light it throws upon the interaction of psychological functions. In Part III these theoretical conclusions are put to the practical test by applying them to the objective criteria of industrial proficiency and accident rate. In order to keep the main argument of the report free from extraneous matter many interesting points arising out of the investigation are given in appendices (p. 62).

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*Farmer, E and Chambers, E G (1926) · A Psychological Study of Individual Differences in Accident Rates —*I F R B Report No.* 38

†Greenwood, M. and Woods H. (1919) : The Incidence of Industrial Accidents upon Individuals, with special reference to Multiple Accidents —*I F R B. Report No.* 4

Greenwood, M and Yule, G. U. (1920) : An Inquiry into the Nature of Frequency Distributions representative of Multiple Happenings with particular Reference to the Occurrence of Multiple Attacks of Disease or of Repeated Accidents.—*J. Roy Stat Soc.* **83,** p 255

Newbold, E M (1926) : A Contribution to the Study of the Human Factor in the Causation of Accidents —*I.F.R.B. Report, No* 34.

The investigation can be divided into the following parts :—

(1) Tests which had been used in the previous investigation were applied to further groups of subjects with the object of seeing how far the results, positive and negative, repeated themselves over a wider field.

(2) All the tests for all the groups were intercorrelated with a view to studying certain aspects of the interaction of psychological functions, and seeing if the intercorrelations of the aesthetokinetic tests among themselves and with other tests were of the same order as had been found in the previous and less extensive data and upon which certain theoretical conclusions had been put forward. This particular part of the work is mainly theoretical, but it examines fundamental principles, and by so doing will aid future investigations.

(3) The relationship between sickness and accident rate and industrial proficiency was re-examined with more extensive data than were available in the first investigation to see whether the tentative suggestions previously put forward were substantiated.

(4) The tests were correlated whenever possible not only with accident rate but also with industrial proficiency.* This was done with the object of finding whether tests which correlated with accident liability also correlated with industrial proficiency, thus serving a dual purpose as selective tests. This problem, although related to the previous one, is clearly distinguishable from it, and by its investigation the present study of accident causation has been brought into line with vocational psychology, so tending to enlarge the connotation of that term and to make its field of application wider by enabling vocational fitness to be measured not only in terms of industrial proficiency, but also in terms of accident proneness.

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* Correlation is a statistical method of measuring the degree of association between two variables. This degree of association is shewn numerically by the "coefficient of correlation" (*r*) which is a number lying between the limits of + 1 and − 1. A correlation coefficient of + 1 indicates that there is perfect association between the two variables, the highest value in the one variable corresponding to the highest in the other, and the lowest in the one corresponding to the lowest in the other. A correlation coefficient of − 1 indicates that there is perfect inverse association between the two variables, the highest value in the one variable corresponding to the lowest in the other, and the lowest in the one corresponding to the highest in the other. Any degree of association falling short of perfection is given as a decimal fraction, either positive or negative.

When the correlation coefficient is large enough to shew a real relationship between the two variables in any group of subjects, the coefficient is said to be "significant".

In order that the sign of the correlation coefficients should always have the same signification, the scores of all tests and objective criteria (industrial proficiency and accident rate) have been arranged so that the lowest numerical score represents the best performance. Hence a positive correlation between a test and accident proneness means that those who do well in the test also tend to have a low (i e good) accident rate. Similarly a positive correlation between a test and industrial proficiency means that those who do well in the test also tend to be good at their trade

(5) The correlation of the tests with industrial proficiency made possible a study in vocational psychology without any specific reference to accident liability and an account of this is given in the report.

(6) New tests which had not previously been applied were given to certain groups of subjects to see how far other psychological functions were concerned in accident liability and industrial proficiency.

The results obtained by intercorrelating all the tests with each other are consistent with the following hypotheses:—

(1) that within selected groups of subjects of the type dealt with in this investigation there is no general factor connecting *all* psychological tests;

(2) that there are well defined *group factors* of a functional nature connecting certain tests;

(3) that tests employing *similar perceptual settings* tend to correlate, even if the functional reactions underlying them are dissimilar.

The coefficients of correlation are throughout small, and their value depends more upon the consistency with which they repeat themselves in different groups of subjects than upon their magnitude. Three explanations are put forward to account for the smallness of the coefficients:—

(1) that the correlation between simple mental functions (e.g., sensori-motor) is less than that between more complex ones (e.g., intelligence);

(2) that the correlations between all tests, mental and other, tend to be smaller among adolescents and adults than among young children, from whom much of the previous knowledge of the nature of intercorrelations has been obtained;

(3) that the subjects tested were selected groups and not typical of a random sample of the population. This will have the effect of automatically reducing the size of the correlation coefficients on account of the lowered standard deviation in selected groups.

When the tests were correlated with industrial proficiency, accidents and sicknesses, the groups of tests that had shown themselves associated in the intercorrelations also had consistent relations with these used as objective criteria. In three of the groups of subjects definite sources of error were present in the accident and sickness records, and in these groups no relation was found between any of the tests and accident rate. In the remaining four groups, whose accident and sickness records were free from these sources of error, the aesthetokinetic group of sensori-motor tests, and to a lesser extent the group of intelligence tests, correlated with accidents though not with sicknesses. In the groups of subjects for which reliable records of industrial proficiency were obtained the aesthetokinetic and intelligence groups of tests correlated positively with proficiency, as did also the dynamometer test, which may be regarded as belonging to a different group of tests of which no other members were used in the each other, although each correlated with industrial proficiency, showing that they measured non-intercorrelating factors among the psychological functions determining industrial proficiency.

Two measures of proficiency were used for these groups of subjects The first was a measure of practical ability alone, and the second a measure of practical and theoretical abilities combined. Each of these measures was used in turn as a basis for weighting the test scores, and the weighted scores obtained in each case were correlated with both these measures of proficiency separately. The correlation between the entrance examination of these subjects and the final proficiency records was **·195*** when practical ability alone was considered, and **·388** when practical and theoretical abilities were taken in conjunction. When, however, the entrance examination was combined with the aesthetokinetic, intelligence and dynamometer tests, each weighted by the two methods mentioned above, the following results were obtained. In the first case, weighting by the practical measure, the correlation of the weighted score with practical ability alone was **·330,** and with practical and theoretical abilities combined **·454.** In the second case, weighting by the combined practical and theoretical measure, the correlation of the weighted score with practical ability alone was **·302,** and with practical and theoretical abilities combined **·472.**

In the groups of subjects which had suitable accident records but no proficiency records, the correlation between the entrance examination alone and accident rate was **·294.** When, however, the entrance examination and the aesthetokinetic tests were weighted according to their relation with accidents, the combined score thus obtained yielded a correlation of **·406** with accident rate. If these tests had been used for selective purposes and the worst 25 per cent. of the subjects rejected, the accident rate of those rejected would have been approximately two and a half times as great as that of the 75 per cent. selected.

In order to find the relation to accidents of tests designed to measure occupational success, the aesthetokinetic, intelligence and dynamometer tests weighted by industrial proficiency were correlated with the accidents of those groups of subjects that had suitable accident records but no industrial records. The correlation was found to be **·446,** which is higher than the correlation of **·294** between their entrance examination and accidents. There is reason, therefore, for supposing that the tests weighted in this way are valid in groups of subjects other than those from which the weights were obtained, and that tests designed to measure occupational success also measure accident proneness.

None of the tests correlated with sicknesses, although sicknesses correlated with accidents and industrial proficiency. None of the tests correlated with proficiency in a markedly different degree in either of the two trades separately examined (fitters and carpenters), showing that these tests at least have no value for determining which particular trade an apprentice should take up but only for indicating general ability in the skilled trades.

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* All significant correlation coefficients in this report are printed in

Part I.—Scope of Investigation.

THE GROUPS TESTED.

Group I consisted of 89 Royal Air Force apprentices who had failed in their final examination and had been put back for further training.

Group II consisted of 85 Royal Air Force apprentices who were highly placed in their final examination.

The accident, sickness and industrial records of these two groups were used in Report No. 38, and are not dealt with in this report. The data obtained from them are only used in considering the nature of the intercorrelations between the tests.

Groups III, IV and V consisted of 524, 259, and 347 Royal Air Force apprentices respectively. Three years' accident and sickness records were obtained for these groups, though in the case of Group V they were slightly incomplete, the full three years' records being obtainable for only 259 of the subjects. Hence in any correlations with accidents and sicknesses only 259 subjects are used in this group. Groups III and IV spent all their time at one training centre, but Group V was changed from one centre to another in the middle of their career. The accident records of Group IV for a period of nine months were dealt with in Report No 38, but those dealt with in this report are for the full period of three years. The trades represented among the R.A.F. apprentices were fitters aero-engine, fitters driver-petrol, fitters armourer, carpenters, coppersmiths and turners.

Groups VI, VII, VIII, IX and X consisted respectively of 57, 100, 94, 70, and 66 Royal Dockyard apprentices. The entrance records of these apprentices have been obtained and also their accident and sickness records, but no records of industrial proficiency were available.

The accident and sickness records for Groups VI, VII, VIII, and IX were for four, three, two and one year respectively. The accidents and sickness records of Group X are not yet available, and the data obtained from this group are only used in dealing with the intercorrelations between the tests.

Groups XI and XII consisted respectively of 83 and 60 naval ratings. The data obtained from these groups are only used in dealing with the intercorrelations of the tests.

TABLE I.—*Age Range and Mean Age of the Groups Tested.* (*Ages are given in years and months*).

Group.	Number of Subjects.	Mean Age.	Age Range
I	89	18–11	18– 0 to 20–0
II	85	18– 6	17–10 ,, 19–9
III	524	18– 3	16– 9 ,, 19–8
IV	259	16– 2	15– 2 ,, 17–8
V	347	18– 9	17– 8 ,, 20–2
VI	57	16– 9	16– 0 ,, 18–0
VII	100	15– 8	15– 0 ,, 17–0
VIII	94	15–11	15– 2 ,, 17–1
IX	70	16– 0	15– 2 ,, 17–6
X	66	16– 1	15– 4 ,, 17–1
XI	83	27– 3	22– 0 ,, 38–0
XII	60	30– 6	23– 1 ,, 41–1

DESCRIPTION OF THE TESTS GIVEN

1. *The dotting test.* The McDougall-Schuster revolving dotting test with an automatic electrical recorder was used. The subject was required to dot a series of small circles passing before him at an increasing speed. Each time he was successful in doing this was automatically recorded on a Veeder counter and the score was the number of his successes. The apparatus is described in Report No. 38, pp. 42, 43.

2. *The pursuit meter test.* The subject was required to follow the irregular movements of a mechanically controlled pointer, deviations from the correct movements being automatically recorded. A graphic method of recording was used for Groups VI and VII, and the apparatus used is described in Report No. 38, pp. 26–28. The numerical method of recording was used for the other groups, and the apparatus employed is described in Report No. 38, pp. 43, 44.

3. *The choice reaction test.* The subject was required to respond to visual, auditory and tactual stimuli as rapidly as possible by placing his finger on the correct response button. The finger always started from the same position and had to travel the same distance for all responses. There were six different stimuli. The subjects were given a series of 30 stimuli and the score consisted of the average time of their responses automatically measured in hundredths of a second. The apparatus is described in Report No. 38, pp. 38–40.

4. *The interrupted pursuit meter test.* The subject was required to do the pursuit meter test as described above. During the test visual and auditory stimuli to which the subject was required to respond were given automatically at irregular intervals. The visual stimuli were red and white discs. When either of these appeared the subject was required to press the appropriate

response button with his left hand. The auditory stimuli were a bell and a buzzer. When the one sounded the subject was required to depress his right foot, and when the other sounded his left. The pursuit meter score was automatically recorded as before, and the number of correct responses made to the reaction stimuli was electrically recorded on a Veeder counter. The score for the whole test was taken as the sum of these two scores, each score being previously expressed as a percentage of its own mean, thus giving the two parts of the test equal weight. The apparatus is described on p 76.

5. *The co-ordination test.* The subject was required to keep a green disc exactly above a white disc which was mechanically moved in an irregular way. He controlled the green disc by means of two handles, one being held in each hand. The right handle moved the disc either towards or away from him, and the left handle moved it either to the right or to the left. The position of the disc was thus a result of the co-ordination between the two hands. Any deviation between the two discs was automatically recorded. The apparatus is described on page 74.

6. *The steadiness test.* The subject was required to keep a stylus with a ball on the end inside a small metal cup without touching either the sides or the bottom, the cup meanwhile being automatically moved in an irregular way. Whenever the ball touched the cup a buzzer sounded and the length of time the two were in contact was automatically recorded. The apparatus is described on page 75. All the above tests were designed and made by Dr. Edgar Schuster.

7. *The rectangles test.* The subject had to form a rectangle out of four pieces of metal, there being only one possible way ot doing so. He was required to form four rectangles in this way, the pieces of metal being cut into different shapes in each case. The pieces of the rectangle were placed in the same position for each subject. The score was the time taken to do the test. No subject was allowed more than three minutes to do any one rectangle.

8. *The strip test.* The subject was required to fit strips of metal of varying length into a frame which they exactly filled if placed in their proper positions. The strips were placed in the same position for each subject. The score was the time taken, no subject being allowed more than three minutes to complete the test. The investigators are indebted to Mr. M. H. Tagg for the use of tests 7 and 8.

9. *The cube test.* The subject was required to build a cube from 27 bricks so that each side of the cube was a different colour. The bricks are coloured in such a way that there can be only one correct solution. The score is the time taken, no subject being allowed more than ten minutes to complete the task.

10. *The linguistic intelligence test.* Group test No. 33, designed by Professor Cyril Burt and obtained from the National Institute of Industrial Psychology, was used. The subjects were

allowed a given time to do each part of the test, the score being the number of correct solutions underlined. The paper comprises an opposites test, an analogy test, a mixed sentence test, a completion test and a reasoning test.

11. *The number setting test.* The subject was required to get a certain combination of figures by moving various levers, one set of levers causing certain combinations to appear and another set causing them to disappear. The combinations they were required to get involved the operation of not less than three levers. The score was the time taken to do the given combinations. The apparatus was designed by Dr. Edgar Schuster, and is described in Report No. 38, pp. 40-42.

12. *The stereoscopic test.* A test card kindly supplied by Messrs. Zeiss was used, the subject having to place in their correct perspective certain pictures on the card when seen through a Zeiss stereoscope. The score was the deviation between the subjects' placing of the pictures and the actual order as given by the various binocular angles of the objects.

13. *The dynamometer test.* The subjects were required to grip a Salter's dynamometer with each hand in succession, the score being the sum of the two grips measured in kilogrammes.

TABLE II.—*Showing which Tests were given to the Different Groups of Subjects and the Total Number of Subjects Examined by Each Test.*

Test	Groups Tested.												Total No. of Subjects.
Dotting ..	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	1834
Linguistic intelligence	I	II	III	IV	V	—	—	VIII	IX	X	XI	XII	1677
Number setting	I	II	III	IV	V	—	—	VIII	IX	X	XI	XII	1677
Reaction time	I	II	III	IV	—	VI	VII	VIII	IX	—	XI	XII	1421
Dynamometer	—	—	III	IV	V	—	—	—	IX	X	—	—	1266
Pursuit meter	I	II	—	IV	—	VI	VII	VIII	—	—	XI	XII	827
Rectangles ..	—	—	—	IV	V	—	—	—	—	X	—	—	672
Strip.. ..	—	—	—	IV	V	—	—	—	—	X	—	—	672
Cube.. ..	—	—	—	IV	V	—	—	—	—	X	—	XII	732
Interrupted pursuit meter.	—	—	III	—	—	—	—	—	IX	—	—	—	594
Co-ordination	—	—	III	—	—	—	—	—	IX	X	—	XII	720
Steadiness ..	—	—	—	—	—	—	—	—	IX	X	—	XII	196
Stereoscope ..	—	—	—	—	V	—	—	—	—	X	—	—	413

PART II.—The Intercorrelation of the Tests.

INTRODUCTION.

Before the relation between the tests and the objective criteria of industrial proficiency and accident and sickness rate is considered, it is advisable to examine the intercorrelations between the tests themselves. The relation between tests is mainly of theoretical interest, but it is none the less important on that account, and any conclusions that can be arrived at from this relationship will be a contribution to the study of the interaction of psychological functions. Moreover, if certain tests can be grouped together on account of some common factor in their performance, it will facilitate subsequent discussions by making it possible to refer to this common factor instead of enumerating on each occasion the tests in which it is involved.

It must, of course, always be borne in mind that to group certain tests together and give them a common name only implies that they intercorrelate positively, and that the name chosen is based on a reasonable guess at the nature of the factor affecting their intercorrelations.

A positive correlation between two or more tests, in so far as it is not due to chance, may be due wholly or partly to the three causes. In the first place, there may be a general factor involved in *all* psychological tests which would cause any and all tests to intercorrelate. This hypothesis can be ruled out if certain tests are found not to correlate with certain other tests, and other hypotheses must be resorted to.

Secondly, a factor may be involved in certain tests and not in others, so that the tests in which it operates tend to correlate among themselves, but not with other tests in which that factor does not operate in a marked degree. According to this hypothesis the intercorrelations between each of the tests in any group of tests is due to some common psychological function involved in the performance of these tests. In order that this hypothesis may be adequate to explain the whole of the data the following conditions must be satisfied :—

> there must be no general intercorrelation between all tests ;
>
> certain tests must intercorrelate positively between themselves and so form groups of intercorrelating tests ;
>
> particular tests in these groups must not correlate with particular tests belonging to other groups in a very different degree from the intercorrelation between the groups as a whole.

The hypothesis cannot be wholly ruled out if the second condition is fulfilled, although the other two may not be fulfilled.

Thirdly, every psychological test involves a cognitive and a functional aspect, and tests may intercorrelate either on account of cognitive or functional similarity. The cognitive aspect involves the perceptual setting or medium employed in the technique of the test; the functional aspect involves a performance reaction. Hence, intercorrelations between tests may be due not to what may be called a common functional performance reaction but to a *similarity between the perceptual setting of the tests.* For example, the Steadiness test correlates positively with the Dotting test, but not with the other aesthetokinetic tests, although Dotting does. It is clear, therefore, that the factor that causes all the aesthetokinetic tests to intercorrelate positively is not the same factor that determines the correlation between Dotting and Steadiness. Both of these tests, however, appear to involve a similar perceptual setting or medium. In the dotting test the subject is required to dot small moving circles with a stylus and in the steadiness test he is required to hold a stylus in a small moving circular cup. The positive correlation that exists between these two tests (and other examples of a like kind will be found in the intercorrelation tables) may be due to a similarity between the perceptual settings of the two tests and not to a common functional performance reaction which is presumably the cause of the positive correlation between dotting and the other aesthetokinetic tests. In order that this hypothesis may adequately account for the whole of the data, only tests with evident similarity in their perceptual setting must correlate, but it cannot be entirely ruled out if there are any tests which correlate and also have a similar perceptual setting.

It will be seen from the above that each of these three hypotheses can be true at the same time, and each in part account for intercorrelations between tests, and only under the conditions mentioned in each case can any one of these exclude the others.

It is not suggested that any of these hypotheses in the crude form in which they have been presented have been put forward previously by any psychologist to account for the nature of the intercorrelations between psychological tests. They have been mentioned in these introductory remarks merely to indicate logical possibilities which must be examined before any psychological hypothesis can be put forward concerning the intercorrelation of the tests, and so facilitate an understanding of the intercorrelation tables and the comments that accompany them. Their adequacy to explain the data can only be considered after the intercorrelation tables have been examined and the whole question will be raised again and more fully discussed at the end of Part II.

TABLE OF INTERCORRELATIONS.

The intercorrelations of each of the tests are given in separate tables since a single table showing the correlation coefficients of all the groups separately would be too bulky to be readily understood. A table of convenient size of all the intercorrelations could have been made using the weighted means only, but this method of presentation has not been adopted because to do so would have implied that each of the correlation coefficients was of equal reliability. It is, of course, obvious that far greater reliance can be placed upon the intercorrelations of tests that have been given to several different groups than upon those where the tests have only been given to one or two groups. Moreover, by showing the data in full it is easier to form an opinion as to the relative consistency of the correlations between different tests. No conclusions will be drawn concerning the intercorrelation of tests unless they have been given to several groups. Coefficients obtained from tests that have only been given once or twice are included for the sake of completeness and to illustrate the probable direction of conclusions that may ultimately be drawn from more extensive data.

Intelligence, as measured by the linguistic test used, correlates to about the order of ·10 with the aesthetokinetic tests* (reaction dotting and pursuit meter). With the interrupted pursuit meter and co-ordination tests the correlation coefficients, though not so numerous, are slightly higher. These latter tests were designed with the object of complicating aesthetokinetic tests, and they are undoubtedly more difficult both to perform and to understand, so that the slightly higher correlations with intelligence are to be expected. There is no correlation with the rectangles and strip tests which depend upon form perception and, in the opinion of the investigators, a good deal upon chance also. There is a correlation of about ·20 with cube and number setting—two performance intelligence tests. There is no correlation with strength as measured by the dynamometer. The correlations with steadiness and stereoscopic vision are not sufficiently reliable on account of the smallness of numbers involved to permit of definite conclusions.

The general inference to be drawn from the intercorrelations of linguistic intelligence with the other tests is that they are for the most part so small as to suggest that the operation of intelligence as a unifying factor in the performance of *all* tests is practically negligible, the only coefficients large enough to warrant serious attention being those with other tests involving intelligence. This is no criticism of the hypothesis that there is a general factor of intelligence. If intelligence be regarded as innate general

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* *See* I.F.R.B. Report No. 38, pp. 4, 5, and British Journal of Psych. 1927, Vol. XVII, Part 4, p 327: "A Group Factor in Sensori-motor Tests." Farmer, E.

These three tests which were found to intercorrelate among themselves to the order of about ·25 were called aesthetokinetic tests because their successful performance requires accurate and rapid co-ordinated reaction to perceptual stimuli, although the form or perceptual setting of the tests differs considerably. They therefore form a special group of sensori-motor tests, distinguishable from sensori-motor tests in general. The data presented later in this report confirms the original conclusions and so the term "aesthetokinetic" will continue to be used as originally defined.

TABLE III.—*Correlation Coefficients between* LINGUISTIC INTELLIGENCE *and the other Tests.*

Group.	No. of Subjects	Aesthetokinetic Tests.					Form perception Tests		Intelligence Tests.		Other Tests.		
		Simple			Complex				Performance.				
		Re-action.	Dotting.	Pursuit meter	Inter-rupted Pursuit meter.	Co-or-dination	Rect-angles.	Strip	Cube.	Number Setting	Stereo-scope.	Dynamo-meter.	Steadi-ness.
I	89	·041	·024	·147	—	—	—	—	—	**192**	—	—	—
II	85	·136	·021	·175	—	—	—	—	—	·024	—	—	—
III	524	·069	**·096**	—	**·144**	**·185**	—	—	—	**·207**	—	—·035	—
IV	259	**·112**	·064	·080	—	—	—·012	**·117**	**·255**	**·216**	—	·060	—
V	347	—	**·152**	—	—	—	·084	—·011	**·203**	**·142**	**·137**	·058	—
VIII ..	94	**·351**	·163	—·018	—	—	—	—	—	·156	—	—	—
IX	70	·093	**·277**	—	·074	·172	—	—	—	**·287**	—	·034	·162
X	66	—	—·158	—	—	—·030	—·153	·057	·079	·118	—·121	—**·240**	—·092
XI ..	83	**·264**	·150	·108	—	—	—	—	—	**·277**	—	—	—
XII ..	60	·133	·191	·180	—	**·312**	—	—	·066	·178	—	—	**·232**
Weighted means	—	·118	·102	·100	**·136**	**·174**	·024	·045	**·200**	**·184**	·096	·003	·094

intellectual ability, then we should expect it to enter to an appreciable extent only into those tests where the intellectual element is predominant. The present data are not inconsistent with the hypothesis of a general factor of intelligence thus defined, since this linguistic intelligence test correlates with the performance intelligence tests (cube and number setting). It may be that with children and sub-normal adults the correlation between intelligence and sensori-motor performance tests would be higher, since among them the differentiation of mental abilities is not so advanced, but within the limits of the present data, which refer to superior adolescents and normal adults, there is no reason to suppose that intelligence plays an important part in sensori-motor ability at the aesthetokinetic level. In the lowly developed individual intelligence is one of the main factors in performance reactions both in psychological tests and in the ordinary conduct of life, but as development takes place these reactions become more and more dependent upon special abilities and habit formations. This process continues until these functions are relatively independent of intelligence, and it is upon these semi-independent functions that the performances of adult life largely depend.

The correlation coefficients of the cube test are not very numerous, although in certain cases they are based upon sufficiently large numbers of subjects to warrant tentative conclusions being put forward. The relation between the cube test and the aesthetokinetic tests is neither close nor consistent. The higher correlations of the cube test with the co-ordination test is in accordance with the evidence derived from the relation between the linguistic intelligence test and the complex aesthetokinetic tests, which indicates that intelligence plays a greater part in these tests than in the simple aesthetokinetic tests. There is a slight relationship between the cube test and the tests depending on form perception (rectangles and strip), and it is higher in the case of the rectangles tests, in which the factor of chance appears from observation to be less operative than in the strip test.

There is a correlation of the order of ·20 between the cube test and the other intelligence tests (number setting and linguistic). The coefficients of correlation between the cube test and stereoscopy accord with the possibility that these two tests have a common visual perceptual function, but the evidence is too slender to be conclusive. There is no relation between strength (dynamometer) and the cube test, and the evidence as to the relation between the steadiness and cube tests is too insignificant and inconsistent to warrant any comment.

The general conclusions to be drawn from the correlation coefficients in Table IV are that they are consistent with the hypothesis that intelligence, form perception, and possibly some visual perceptual function connected with stereoscopy are all involved in the cube test, although none of these factors necessarily correlate independently.

TABLE IV.—*Correlation Coefficients between* CUBE *and the other Tests.*

Group.	No. of Subjects	Aesthetokinetic Tests.					Form Perception Tests		Intelligence Tests.		Other Tests.		
		Simple.			Complex.				Performance.	Linguistic.			
		Re-action.	Dotting	Pursuit meter.	Interrupted Pursuit meter	Co-ordination	Rect-angles	Strip.	Number setting.		Stereo-scope.	Dynamo-meter.	Steadi-ness.
IV	259	**·192**	·059	·001	—	—	**·134**	·014	**·150**	**255**	—	·005	—
V	347	—	**·102**	—	—	—	**·156**	**·120**	**·256**	**·203**	**·148**	**·113**	—
X	66	—	·015	—	—	**·222**	**·326**	**·295**	·114	·079	·135	—·098	·176
XII ..	60	·177	—·045	—·024	—	**·281**	—	—	·124	·066	—	—	—·060
Weighted means.	—	**·189**	·067	—·004	—	**·250**	**·164**	·096	**·195**	**·200**	**·146**	·051	·064

TABLE V.—*Correlation Coefficients between* NUMBER SETTING *and the other Tests.*

Group.	No. of Subjects.	Aesthetokinetic Tests.					Form Perception Tests.		Intelligence Tests.		Other Tests.		
		Simple.			Complex.								
		Re-action.	Dotting	Pursuit meter.	Inter-rupted Pursuit meter	Co-ordination	Rect-angles.	Strip.	Per-form-ance	Lingu-istic	Stereo-scope.	Dynamo-meter.	Steadi-ness.
									Cube.				
I	89	·166	—·097	·014	—	—	—	—	—	**·192**	—	—	—
II	85	—·099	—·079	—·121	—	—	—	—	—	·024	—	—	—
III	524	**·127**	·042	—	**·202**	**·187**	—	—	—	**·207**	—	—·046	—
IV	259	**·137**	**·114**	—·041	—	—	·058	—·036	**·150**	**·216**	—	—·004	—
V	347	—	**·093**	—	—	—	·034	·064	**·256**	**·142**	—·037	—·004	—
VIII ..	94	**·194**	—·010	—·125	—	—	—	—	—	·156	—	—	—
IX	70	**·281**	·138	—	·091	**·203**	—	—	—	**·287**	—	·060	— 078
X	66	—	—·019	—	—	·030	**·224**	·125	·114	·118	—·011	—**·206**	—·021
XI	83	**·344**	**·212**	**·241**	—	—	—	—	—	**·277**	—	—	—
XII ..	60	·067	·053	·125	—	**·318**	—	—	·124	·178	—	—	174
Weighted means.	—	**·142**	·058	—·006	**·189**	**·185**	·062	·032	**·195**	**·184**	—·033	—·028	·018

There is no general relationship between the number setting test and the aesthetokinetic tests, although there is a slight relationship with the choice reaction test. In this connection it is interesting to note that the coefficients of correlation of the three intelligence tests (linguistic intelligence, cube and number setting) are always higher with reaction than with any other of the aesthetokinetic tests. There is little doubt that the choice reaction test is more difficult to understand than either the dotting or pursuit meter tests, and this may be the reason why intelligence appears to play a slightly higher part in its performance than it does in the other aesthetokinetic tests. The coefficients of correlation between the number setting test and the complex aesthetokinetic tests (interrupted pursuit meter and co-ordination) are similar to those obtained from the other intelligence tests and are consistent with the hypothesis that these tests involve intelligence in their performance. The correlation of the number setting test with the other intelligence tests (linguistic and cube) are of about the same order as that found between all the intelligence tests. There is no relation between the form perception tests (rectangles and strip) and the number setting test. The only intelligence test that correlates at all with the form perception tests is the cube test, which is the only one that by observation involves form perception. This correlation is, therefore, presumably due to a similarity between the perceptual setting of the tests and not to some common functional performance factor. The fact that the cube test correlates with stereoscopy whereas the intelligence and number setting tests do not is consistent with this suggestion. There is no relationship between the number setting and dynamometer tests.

The three tests, linguistic intelligence, number setting and cube, are referred to as the *intelligence tests*, since they were designed to test intelligence expressed through different media, and have been found to intercorrelate among themselves and to correlate slightly with the complex aesthetokinetic tests, which are undoubtedly difficult to understand as well as to perform. The cube test is the only one of these which correlates with tests with which the others do not correlate. The three tests it correlates with (rectangles, strip and stereoscopy) involve either form perception or judgments involving depth perception, both of which are by observation involved in the cube test. It is, therefore, suggested that the correlations in these cases are due to a similarity between the perceptual settings of the tests, and not to the common factor of intelligence which is presumably the uniting link between the intelligence tests themselves, since their perceptual settings differ. This suggestion will receive further consideration when the intercorrelations of the other tests have been examined.

The dotting test correlates with the other aesthetokinetic tests (reaction and pursuit meter), and also with the complex aesthetokinetic tests (interrupted pursuit meter and co-ordination). The correlation between dotting and steadiness is possibly due to

TABLE VI.—*Correlation Coefficients between* DOTTING *and the other Tests.*

Group.	No. of Subjects.	Aesthetokinetic Tests				Form Perception Tests		Intelligence Tests			Other Tests		
		Simple.		Complex		Rect-angles	Strip	Performance		Lingu-istic	Stereo-scope	Dynamo-meter	Steadi-ness
		Re-action.	Pursuit Meter	Inter-rupted Pursuit meter.	Co-ordination			·Cube	Number Setting				
I	89	**·309**	**·221**	—	—	—	—	—	—·097	·024	—	—	—
II	85	**·186**	**·234**	—	—	—	—	—	—·079	021	—	—	—
III	524	**·254**	—	**·264**	**·279**	—	—	—	·042	**·096**	—	075	—
IV	259	**·260**	**·342**	—	—	·100	·062	059	**·114**	·064	—	·017	—
V . ..	347	—	—	—	—	·009	—·026	**102**	**·093**	**·152**	**127**	**140**	—
VI . .	57	**·350**	**·390**	—	—	—	—	—	—	—	—	—	—
VII ..	100	**·230**	**·280**	—	—	—	—	—	—	—	—	—	—
VIII ..	94	**·220**	**·398**	—	—	—	—	—	—·010	·163	—	—	—
IX	70	·042	—	**·196**	**·288**	—	—	—	·138	**·277**	—	·169	·183
X	66	—	—	—	**261**	·145	**·301**	·015	—·019	—·158	·021	·119	**·399**
XI	83	**·318**	**·518**	—	—	—	—	—	**·212**	·150	—	—	—
XII ..	60	**·272**	**·338**	—	·065	—	—	—·045	·053	·191	—	—	·156
Weighted means.	—	**·248**	**·337**	**·256**	**·260**	·057	040	·067	·058	·102	·110	·088	**·247**

the similarity between the perceptual settings of the tests, the subject having in the one case to dot moving circles with a stylus and in the other hold a stylus inside a moving circular cup. The remaining correlation coefficients, where the data are sufficient to warrant any conclusions, are so small as to indicate a complete lack of relationship between dotting and all the other tests.

The pursuit meter test correlates with the other aesthetokinetic tests but with none of the remaining tests, where the data are sufficient to warrant any conclusions at all.

The choice reaction test correlates with the simple aesthetokinetic tests (dotting and pursuit meter), and with the complex aesthetokinetic tests. It also correlates with the intelligence tests to a small degree, a result which agrees with the suggestion already put forward that choice reaction involves intelligence for its successful performance in a slightly higher degree than the other aesthetokinetic tests.

An examination of Tables VI, VII and VIII shows that the aesthetokinetic tests correlate among themselves and with the complex aesthetokinetic tests, where the data are sufficient to draw any conclusions at all. They do not as a whole correlate with any other of the tests, although the choice reaction test, which by observation is more difficult to understand and perform than the others, correlates to a slight degree with the intelligence tests. There appears, therefore, every justification for regarding these tests as measuring some common sensori-motor factor which may be called aesthetokinetic co-ordination. There may, of course, be other ways of measuring it, and it may also play a part in other tests, but it is useful for experimental purposes to have segregated a particular type of sensori-motor ability and to have found methods of measuring it. The dissimilarity of the methods and movements involved in the tests precludes the possibility of their intercorrelations with one another being due to similarity in perceptual setting, so that the relationship between the tests can only be explained on the assumption of a common functional factor measured in different ways by all three of the tests. It has been shown that this factor is not intelligence, since only one of the aesthetokinetic tests correlates with the intelligence tests, and the assumption is that it is a particular type of sensori-motor co-ordination. It does not follow that there is a factor common to all sensori-motor tests, but only that there is one common to this particular group of tests, which measure sensori-motor ability at one level only.

Although the perceptual settings of these three tests differ, yet in each test afferent nervous impulses received through some specific sense organ have to be interpreted by the subject as a sign for varying muscular performances, and if the tests are to be carried out efficiently these signs and the muscular performances to which they are intended to lead must be accurately co-ordinated. The degree of co-ordination required for a successful performance

TABLE VII.—*Correlation Coefficients between* PURSUIT METER *and the other Tests*

Group.	No. of Subjects.	Aesthetokinetic Tests.				Form Perception Tests		Intelligence Tests			Other Tests.		
		Simple.		Complex		Rect-angles.	Strip.	Performance		Lingu-istic.	Stereo-scope.	Dynamo-meter.	Steadi-ness.
		Re-action.	Dotting.	Inter-rupted Pursuit meter.	Co-or-dination			Cube.	Number setting.				
I	89	**·213**	**·221**	—	—	—	—	—	·014	·147	—	—	—
II	85	·095	**·234**	—	—	—	—	—	—·121	·175	—	—	—
IV	259	**·206**	**·342**	—	—	·097	·001	·001	—·041	·080	—	·081	—
VI	57	·240	**·390**	—	—	—	—	—	—	—	—	—	—
VII ..	100	·090	**·280**	—	—	—	—	—	—	—	—	—	—
VIII .	94	·072	**·398**	—	—	—	—	—	—·125	— 018	—	—	—
XI	83	**240**	**·518**	—	—	—	—	—	**·241**	·108	—	—	—
XII ..	60	**·389**	**·338**	—	·028	—	—	—·024	·125	·180	—	—	—·001
Weighted means.	—	**·185**	**·337**	—	028	·097	·001	—·004	— 006	·100	—	·081	—·001

TABLE VIII.—*Correlation Coefficients between* REACTION TIME *and the other Tests.*

Group.	No. of Subjects	Aesthetokinetic Tests.				Form Perception Tests		Intelligence Tests.			Other Tests.		
		Simple.		Complex		Rectangles	Strip	Performance		Linguistic.	Stereoscope	Dynamometer	Steadiness.
		Dotting	Pursuit meter	Interrupted Pursuit meter	Co-ordination			Cube	Number setting				
I	89	**·309**	**·213**	—	—	—	—	—	·166	·041	—	—	—
II	85	**·186**	·095	—	—	—	—	—	—·099	·136	—	—	—
III	524	**·254**	—	**·244**	**·165**	—	—	—	**·127**	·069	—	·028	—
IV	259	**·260**	**·206**	—	—	**·106**	·074	**·192**	**·137**	**·112**	—	·086	—
VI .. .	57	**·350**	**·240**	—	—	—	—	—	—	—	—	—	—
VII ..	100	**·230**	·090	—	—	—	—	—	—	—	—	—	—
VIII ..	94	**·220**	·072	—	—	—	—	—	**·194**	**·351**	—	—	—
IX	70	·042	—	**·273**	—**·197**	—	—	—	**·281**	·093	—	·064	—·135
XI	83	**·318**	**·240**	—	—	—	—	—	**·344**	**·264**	—	—	—
XII ..	60	**·272**	**·389**	—	·148	—	—	·177	·067	·133	—	—	·046
Weighted means.	—	**·248**	**·185**	**·247**	**·125**	**·106**	·074	**·189**	**·142**	·118	—	·049	—·051

in these tests is more complex than that common to all sensori-motor tests among which no intercorrelation has been found,* and less complex than that required for successful performance in the complex aesthetokinetic tests. The complex aesthetokinetic tests correlate positively with the intelligence tests, while the simple aesthetokinetic tests as a whole do not. Successful performance in these tests is in part, therefore, dependent upon a common factor not present in all sensori-motor tests and relatively independent of intelligence, and it is proposed to call this common factor aesthetokinesis† and regard it as a particular type of sensori-motor co-ordination.

The data concerning the remaining tests are, with the exception of the dynamometer, markedly less extensive than those obtained from the tests already dealt with. Any conclusions arrived at will, therefore, be put forward with considerable diffidence, and the main object in examining their intercorrelations is to see how far they are consistent with the hypotheses already put forward and based upon more extensive data.

The co-ordination test, which is one of the complex aesthetokinetic tests, correlates with the simple aesthetokinetic tests and with the interrupted pursuit meter test. (The single coefficient between co-ordination and pursuit meter is too insignificant to warrant any attention at all.) It also correlates with the intelligence tests, which indicates that intelligence plays a certain part in its performance—a conclusion already arrived at by observation. The correlation with the steadiness test may be due to a similarity between the perceptual settings of the tests, for in the co-ordination test the subject is required to keep a disc, which he controls, immediately above a moving disc, and in the steadiness test he is required to keep a stylus inside a moving cup, the disc in the one case and the cup in the other moving in the same space and velocity pattern.

The interrupted pursuit meter test correlates with the simple aesthetokinetic tests and with co-ordination. It also correlates with the intelligence tests.

The coefficients obtained from the interrupted pursuit meter and co-ordination tests are consistent with the hypothesis that they form a special group of tests in the same way as the aesthetokinetic and intelligence tests. They correlate with the aesthetokinetic tests, with the intelligence tests and with themselves, and the only case where one of them correlates with a test and the other does not (co-ordination with steadiness) is possibly

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* Perrin: "An experimental study of motor ability." *J. Exper. Psychol.* 1921, IV, pp. 24–56.

Muscio, B.: "Motor ability with special reference to Vocational Guidance." *Brit. J. Psychol.* 1922, XIII, Part 2, pp 157–185.

Farmer, E.: "A Group Factor in Sensori-motor Tests." *Brit. J. Psychol.* 1927, XVII, Part 4, pp. 327–334.

† I.F.R.B. Report No. 38, p. 4.

TABLE IX.—*Correlation Coefficients between* CO-ORDINATION *and the other Tests.*

Group.	No. of Subjects.	Aesthetokinetic Tests.				Form Perception Tests.		Intelligence Tests.			Other Tests.		
		Simple.			Complex			Performance.					
		Re-action.	Dotting	Pursuit meter.	Inter-rupted Pursuit meter.	Rect-angles	Strip	Cube.	Number setting.	Lingu-istic.	Stereo-scope.	Dynamo-meter.	Steadi-ness.
III	524	**·165**	**·279**	—	**·254**	—	—	—	**·187**	**·185**	—	·029	—
IX	70	—**·197**	**·288**	—	**·307**	—	—	—	**·203**	·172	—	·055	·080
X	66	—	**·261**	—	—	·187	·083	**·222**	·030	—·030	·065	·104	·184
XII ..	60	·148	·065	·028	—	—	—	**·281**	**·318**	**·312**	—	—	·157
Weighted means	—	**·125**	**·260**	·028	**·260**	·187	·083	**·250**	**·185**	**·174**	·065	·039	·139

TABLE X.—*Correlation Coefficients between* INTERRUPTED PURSUIT METER *and the other Tests.*

Group.	No. of Subjects.	Aesthetokinetic Tests				Form Perception Tests.		Intelligence Tests.			Other Tests.		
		Simple.			Complex			Performance.		Lingu-istic.			
		Re-action.	Dotting	Pursuit meter	Co-ordination.	Rect-angles.	Strip.	Cube.	Number setting.		Stereo-scope.	Dynamo-meter.	Steadi-ness.
III ..	524	**·244**	**·264**	—	**·254**	—	—	—	**·202**	**·144**	—	·053	—
IX ..	70	**·273**	**·196**	—	**·307**	—	—	—	·091	·074	—	·004	·039
Weighted means.	—	**·247**	**·256**	—	**·260**	—	—	—	**·189**	**·136**	—	·047	·039

due to a similarity between the perceptual media of the two, and will be dealt with when discussing the intercorrelations of the steadiness test.

The complex aesthetokinetic tests were originally designed with a view to testing a higher level of sensori-motor co-ordination segregated from other psychological functions, but an examination of their intercorrelations with other tests leads to the conclusion that this has not been done, but that an intelligence factor has been introduced into these tests from which the simple aesthetokinetic tests were relatively free. It would appear that the more difficult forms of sensori-motor co-ordination are dependent partly upon intelligence for their efficient operation and not solely upon a pure sensori-motor factor at a higher level than that measured by the simple aesthetokinetic tests. This hypothesis would be consistent with the fact that sensori-motor tests correlate with intelligence among young children, and still more among the mentally defective, for it implies that when sensori-motor co-ordination presents undue difficulty intelligence comes to the aid of the undeveloped sensori-motor system. Young children, with their less developed muscular control, probably find as much difficulty in performing the simple aesthetokinetic tests as adults find in performing the complex ones, so that in both cases the tests become to some degree tests of intelligence.

The function of intelligence in relation to sensori-motor co-ordination seems to be to aid habit formations. When these are sufficiently developed, they are able to function relatively independently of intelligence, but if situations are presented calling for unduly complicated co-ordination reactions the habit formations, on which the less complicated co-ordinations depend, are inadequate and intelligence enters into the response. The degree of complexity in a sensori-motor co-ordination required to call forth an intelligence response will in some degree depend upon the age of the subject since age is one of the dominant factors in habit formation and muscular control. But it is also possible that certain sensori-motor co-ordinations are sufficiently difficult to call forth an intelligence response in fully developed adults.

The rectangles test correlates with the strip test. Both these tests were designed to measure form perception, but they both use the same perceptual medium, i.e., putting pieces of metal in their correct positions. It is, therefore, left indeterminate whether their relation is due to a similarity of perceptual setting or to some common performance factor. The correlation between the rectangles and cube tests is probably due to the fact that both involve form perception. This has already been alluded to in discussing the data presented in Table IV. The correlations between rectangles, steadiness and co-ordination are for one group only, and no conclusions are drawn from them.

TABLE XI.—*Correlation Coefficients between* RECTANGLES *and the other Tests.*

Group.	No of Subjects.	Aesthetokinetic Tests.					Form Perception Tests.	Intelligence Tests.			Other Tests.		
		Simple.			Complex			Performance.					
		Re-action.	Dotting.	Pursuit meter.	Inter-rupted Pursuit meter.	Co-ordination	Strip.	Cube	Number setting.	Linguistic.	Stereo-scope	Dynamo-meter.	Steadi-ness.
IV	259	**·106**	·100	·097	—	—	**·147**	**·134**	·058	—·012	—	—·007	—
V	347	—	·009	—	—	—	**·196**	**·156**	·034	·084	·041	·012	—
X	66	—	·145	—	—	·187	**·207**	**·326**	**·224**	— 153	·017	— 067	**·257**
Weighted means.	—	**·106**	·057	·097	—	·187	**·178**	**164**	062	·024	·037	— 003	**·257**

TABLE XII.—*Correlation Coefficients between* STRIP *and the other Tests.*

Group.	No. of Subjects.	Aesthetokinetic Tests.					Form Percep-tion Tests.	Intelligence Tests.			Other Tests.		
		Simple.			Complex.			Performance.		Lingu-istic.	Stereo-scope.	Dynamo-meter.	Steadi-ness.
		Re-action.	Dotting	Pursuit meter.	Inter-rupted Pursuit meter.	Co-or-dination.	Rect-angles	Cube.	Number setting.				
IV	259	·074	·062	·001	—	—	**·147**	·014	—·036	**·117**	—	·018	—
V	347	—	—·026	—	—	—	**·196**	**·120**	·064	—·011	—·010	·028	—
X	66	—	**·301**	—	—	·083	**·207**	**·295**	·125	·057	·181	—·046	·058
Weighted means.	—	·074	·040	·001	—	·083	**·178**	·096	·032	·045	·021	·017	·058

TABLE XIII.—*Correlation Coefficients between* STEREOSCOPE *and the other Tests.*

Group.	No. of Subjects.	Aesthetokinetic Tests.					Form Perception Tests.		Intelligence Tests.			Other Tests.	
		Simple.			Complex.				Performance.				
		Re-action.	Dotting.	Pursuit meter.	Interrupted Pursuit meter.	Co-ordination.	Rectangles	Strip.	Cube.	Number setting	Linguistic.	Dynamometer.	Steadiness.
V	347	—	**·127**	—	—	—	·041	—·010	**·148**	—·037	**·137**	·067	—
X	66	—	·021	—	—	·065	·017	·181	·135	—·011	—·121	—·063	·043
Weighted means.	—	—	·110	—	—	·065	·037	·021	**·146**	—·033	·096	·046	·043

The strip test correlates consistently only with the rectangles test and this has already been alluded to.

The stereoscopic test correlates with the cube test which definitely involves in some way response to depth. The correlation between dotting and stereoscopy is not inconsistent with there being a real relationship between the two tests, and if further experiments yield this result it might be explained on the assumption that both tests involve some common visual factor.

Since the dynamometer test correlates with none of the other tests, it may be regarded as measuring something not dominant to a noticeable degree in any of them. The dynamometer test is a rough measure of strength, and therefore presumably of physical fitness,* but the fact that within the limits of the present data it does not correlate with the intelligence tests should not be regarded as contrary to the opinion that physical and mental superiority are connected. The subjects examined in this investigation are not typical of the whole population, but belong to groups in which physical and mental selection has taken place. The only interpretation that can safely be put upon the want of relation between strength and intelligence revealed in the present data is that in groups composed solely of individuals who are possessed of a certain degree of physical and mental superiority there is no relation between variations in physical strength and mental capacity.

The steadiness test correlates only with dotting and co-ordination. These correlations appear to be explicable on the assumption of similarity in the perceptual setting of these tests. In dotting the subject is required to dot small moving circles with a stylus, in steadiness the subject is required to hold a stylus in a small moving circular cup, and in the co-ordination test the subject is required to keep a disc under his control over a moving disc which describes the same space and velocity pattern as the moving cup in the steadiness test.

In view of the fact that steadiness does not correlate consistently with any of the recognised groups of tests and that its correlations with individual tests may all be explained on the basis of similarity of perceptual media, it is best to treat it as an isolated test belonging to some group of which there are no other representatives among the present tests. Until consistent correlations can be obtained between the steadiness test and other tests employing different media, it is inadvisable to hazard a suggestion as to the particular functional factors involved in the test.

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* It should be noted that there is no relationship between the dynamometer test and sicknesses so that the term "physical fitness" used in the text should not be regarded as including relative freedom from sickness in its connotation.

TABLE XIV.—*Correlation Coefficients between* DYNAMOMETER *and the other Tests.*

Group.	No. of Subjects.	Aesthetokinetic Tests.					Form Perception Tests.		Intelligence Tests.			Other Tests.	
		Simple.			Complex.				Performance.				
		Re-action.	Dotting	Pursuit meter	Inter-rupted Pursuit meter.	Co-ordination	Rect-angles.	Strip.	Cube.	Number setting.	Lingu-istic.	Dynamo-meter.	Steadi-ness.
III ..	524	·028	·075	—	·053	·029	—	—	—	—·046	—·035	—	—
IV ..	259	·086	·017	·081	—	—	—·007	·018	·005	—·004	·060	—	—
V	347	—	**·140**	—	—	—	·012	·028	**·113**	—·004	·058	·067	—
IX	70	·064	·169	—	·004	·055	—	—	—	·060	·034	—	·0004
X	66	—	·119	—	—	·104	—·067	—·046	—·098	—**·206**	—**·240**	—·063	·030
Weighted means.	—	·049	·088	·081	·047	·039	—·003	·017	·051	—·028	·003	·046	·015

Table XV.—*Correlation Coefficients between* Steadiness *and the other Tests.*

Group.	No. of Subjects.	Aesthetokinetic Tests.					Form Perception Tests.		Intelligence Tests.			Other Tests	
		Simple.			Complex.		Rect-angles.	Strip	Performance.		Linguistic.	Stereo-scope.	Dynamo-meter.
		Re-action.	Dotting	Pursuit meter.	Inter-rupted Pursuit meter	Co-ordination			Cube.	Number setting			
IX	70	—·135	·183	—	·039	·080	—	—	—	—·078	·162	—	·0004
X	66	—	**·399**	—	—	·184	**·257**	·058	·176	—·021	—·092	·043	·030
XII ..	60	·046	·156	—·001	—	·157	—	—	—·060	·174	**·232**	—	—
Weighted means.	—	—·051	**·247**	—·001	·039	·139	**·257**	·058	·064	·018	·094	·043	·015

GENERAL CONCLUSIONS TO BE DRAWN FROM THE INTERCORRELATIONS OF THE TESTS.

The general conclusions to be drawn from the examination of the intercorrelations of the tests are that within the groups tested there is no general factor making for proficiency in *all* tests, that there are well defined *group factors*, and that tests with *similar perceptual settings* tend to correlate, although the performance factors involved in them may be different.

The tests that have been grouped together are so dissimilar in their media (with the exception of the form perception tests) as to preclude the suggestion that their intercorrelation is due to a similar perceptual setting, and the most reasonable hypothesis appears to be that they measure in various ways and in varying degrees some common functional reaction. Of course, the intercorrelations themselves give no indication of the nature of this common factor, but it is convenient to give it a name, although all that is definitely known about it is that it is the common factor measured by certain tests.

It must be recognised that the distinction between tests which correlate on account of a common performance reaction and those which correlate on account of a similarity in perceptual setting may at times be somewhat arbitrary. Both factors are psychological, and to distinguish between them offers certain theoretical difficulties. The suggestion has been put forward to explain certain features of the correlation tables which may possibly be explained in a more satisfactory way as our knowledge of the factors determining intercorrelation between tests increases, but in the meantime it is a useful practical distinction which may be helpful in devising new tests Although there may be difficulty in drawing a distinction on purely theoretical grounds between the cognitive and functional aspects of a test, yet in practice the difficulty is not so great. It is easy to recognise that certain tests—examples of which have been given in the intercorrelation tables—do involve similar perceptual settings, whether or not they have a common functional performance factor. In devising analogous tests emphasis will be laid upon the similarity of the perceptual setting, so as to make the tests reproduce as accurately as possible certain aspects of the occupation they are supposed to resemble. The main guide a psychologist has in devising analogous tests is the movement cycles of the worker, and if these can be reproduced in the perceptual setting of an analogous test, the presumption is that the test will involve at least one dominant factor in occupational success, whatever other factors it measures or does not measure. In devising tests to measure more general psychological functions than those primarily measured by analogous tests, effort should be directed towards keeping the perceptual settings dissimilar, in order that intercorrelations with other tests may as far as possible be due to a common functional performance factor and not to the perceptual medium of the tests.

Every test involves a group of psychological functions. In young children intelligence seems to be the predominant factor which accounts for the positive correlations of all tests with each other among children. As mental and physical development takes place other functions begin to take a more important part in test performances, so that dominance ceases to belong to one factor and becomes divided among many. This process will tend to lower the correlations between tests, for such correlations will be due not to one predominant factor, but to many equally (or nearly equally) dominant factors. When two tests correlate positively it cannot be assumed that it is due to a common *predominant* factor but merely to a *dominant* factor possessed in common by both tests. Other dominant factors may be present in either test, and may even play a more important part in their performance than the dominant factor they have in common. The fact that a particular psychological factor is present in a test does not imply that others are absent or that it is the most important factor in its performance. An illustration of this is afforded by the complex aesthetokinetic tests which correlate positively with the simple aesthetokinetic tests and also with the intelligence tests, although the simple aesthetokinetic and intelligence tests do not correlate with each other. This means that the complex aesthetokinetic tests possess at least two dominant factors, one of which causes them to correlate with the simple aesthetokinetic tests, and the other with the intelligence tests, and they may have other dominant factors which the present data have not revealed.

The coefficients of correlation are throughout smaller than those usually found between different intelligence tests. Certain reasons can be put forward to explain this.

(1) The correlation between tests of simpler mental functions (such as sensori-motor tests) is less than the correlation between tests of more complex functions (such as intelligence), because tests of the latter type are more likely to contain common factors than tests of the former type. No high intercorrelation coefficients between sensori-motor tests have been reported except among young children and mental defectives, and since among these, sensori-motor tests correlate highly with intelligence the presumption is that the common factor affecting correlation between sensori-motor tests in their case is intelligence and not sensori-motor co-ordination. Neither Perrin nor Muscio found any intercorrelation between sensori-motor tests in general, and the present data only suggests that there is a small positive correlation between certain sensori-motor tests, and not that there is a correlation between sensori-motor tests in general.

(2) Most of the intercorrelations between intelligence tests have been obtained from children, among whom all tests tend to correlate. The subjects whose test performances are dealt with in this report were all past childhood. It has already been pointed out that with increasing age intelligence tends to play a smaller part in performance reactions, these depending more and more upon specialised functions, so that a high correlation between tests is not to be expected. Professor Cyril Burt kindly allowed us to examine the records of a group of 146 adult subjects who had taken the intelligence test used in this investigation. The mean correlation between their scores for the five questions in the test was ·359, which is similar to the correlation of ·378 for our subjects, and is less than that usually obtained between parts of an intelligence test when the subjects are children. Burt has already pointed out that the influence of general ability decreases and that of special abilities increases with age, for in *Mental and Scholastic Tests*, page 266, he says: "With young children, particularly with girls, one can often demonstrate little but the existence of a general factor. With older children, and particularly with college students, little but specific talents or specialised interests." The correlation coefficients presented in this report are consistent with the conclusions already arrived at by Burt as to the effect of age on the correlation between psychological tests. The fact that Burt's subjects were college students, whereas those dealt with in this investigation were skilled apprentices, indicates that any peculiarities in mental bias which may distinguish the two groups do not affect the differentiation of mental functions which is common to both and is apparently a function primarily of age.

(3) Another factor tending to reduce the correlation coefficients obtained from these groups is the relative homogeneity of the groups themselves. The groups tested were not a random sample of the population of their age, but a sample somewhat stringently selected. All the apprentices had passed a moderately difficult examination before entering upon their training. This examination has been found to correlate positively with intelligence, the coefficients being higher in this case than in any other (*see* Table XXV). It is clear, therefore, that entrance by examination has the effect of producing a somewhat more homogeneous group than taking a complete age-group. Burt, who has drawn attention to this factor in testing older samples of the population, has supplied us with the standard deviation of a group of 8,613 ex-service men previously

tested by him for the Civil Service Commission with the linguistic intelligence test used in this investigation.* These ex-service men were drawn from a much wider range than any of our groups, and the standard deviation of their scores in the intelligence paper was 27·2, a figure appreciably higher than that of any of our groups (*see* Table XVI). Accordingly, he has suggested that it might be possible by means of a formula† to estimate the influence of a known degree of relative selection on the correlations obtained in the selected group. When the formula is applied all the coefficients of correlation with intelligence are increased, the results being shown in Table XVII.

TABLE XVI.—*Standard Deviations of the Means of the Scores in the Linguistic Intelligence Test for Different Groups of Subjects.*

Group.	S.d. of Intelligence Test.
I	22·9
II	19·1
III	21·4
IV	21·5
V	21·4
VIII	19·6
IX	19·4
X	17·4
XI	24·3
XII	21·5

The effect of selection by intelligence on the size of the correlation coefficients can be readily measured by means of the standard deviation obtained from Burt's random sample, but no such standard deviation is available for measuring the effect of selection on the basis of factors involved in any of the other tests. It is, however, probable that a similar process of selection has taken place in regard to the functions measured by the aesthetokinetic tests. Before entry the apprentices are medically examined, and those who are unfit rejected. There is no proof that the aesthetokinetic tests measure functions connected with medical fitness, but it seems not unreasonable to suppose that they do. Among a random sample of the population there would be many with defective vision, poor physical development and nervous control, and if these subjects were included in the group their scores in the

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* *Brit. Assoc. Report*, 1923. "Mental Differences between Individuals."

† The formula he has suggested for the purpose is

$$r = \frac{\frac{\sigma}{s}R}{\sqrt{1-\left(1-\frac{\sigma^2}{s^2}\right)R^2}}$$

where R is the observed coeff.,
r is the "corrected" coeff.,
s is the observed s.d and
σ is the "corrected" s.d.

TABLE XVII.—*Observed and Corrected Coefficients of Correlations between Linguistic Intelligence and other Tests.*

Group	I	II	III	IV	V	VIII	IX	X	XI	XII
Number of subjects	89	85	524	259	347	94	70	66	83	60
Reaction	041 (049)	·136 **(·192)**	069 (088)	**·112** **(142)**	— —	**351** (·456)	093 (130)	— —	**264** **(293)**	133 (167)
Dotting ..	024 (029)	021 (030)	096 **(122)**	064 (081)	**152** **(192)**	·163 **(224)**	**277** **·375**	– 158 **(– 242)**	150 (167)	·191 **(239)**
Pursuit meter	147 (·174)	175 **(245)**	— —	080 (102)	— —	– 018 (– 025)	— —	— —	108 (·121)	180 **(·225)**
Interrupted Pursuit meter	— —	— —	**144** (183)	— —	— —	— —	074 (·103)	— —	— —	— —
Co-ordination .	— —	— —	**185** **(233)**	— —	— —	— —	·172 **(238)**	– ·030 (– 047)	— —	**312** **(·384)**
Rectangles	— —	— —	— —	– 012 (– 015)	084 **(107)**	— —	— —	– 153 **(– 235)**	— —	— —
Strip	— —	— —	— —	**117** **(148)**	– ·011 (– ·014)	— —	— —	057 (089)	— —	— —
Cube	— —	— —	— —	**255** **(·318)**	**·203** **(255)**	— —	— —	·079 (·123)	— —	·066 (083)
Number setting	**·192** **(·226)**	024 (·034)	**207** **(260)**	**·216** **(271)**	**142** **(179)**	·156 **(·214)**	**287** **(387)**	·118 (182)	**·277** **(·307)**	·178 **(·223)**
Stereoscope	— —	— —	— —	— —	·137 **(·173)**	— —	— —	– 121 (– ·187)	— —	— —
Dynamometer	— —	— —	– ·035 (– ·045)	·060 (076)	·058 (073)	— —	034 (·045)	**– ·240** **(– 360)**	— —	— —
Steadiness	— —	— —	— —	— —	— —	— —	162 **(224)**	– ·092 (– ·143)	— —	**·232** **(·289)**

Observed and Corrected Correlations between Linguistic Intelligence & Passing-out Exams.

Group.	School	Local Technical	General Efficiency	C T T B	Total.
III . .	**398** (·483)	**173** (·218)	**102** (·129)	**·124** (·157)	**288** (·357)
IV . .	**·455** **(545)**	**·153** (·193)	·048 (061)	·110 **(139)**	**·289** **(358)**
V .	**·409** (495)	**247** **(308)**	·104 (·132)	**·216** (·271)	**·336** **(·413)**

Bracketed figures are correlations corrected for effect of selection on Intelligence

aesthetokinetic tests would almost certainly be less on the whole than those of the medically fit subjects who form the groups tested in this investigation. If this were so, the standard deviation of the tests would be greater in such a heterogeneous group than those obtained from the present data, and by applying the formula given on page 36 the size of the correlation coefficients with the aesthetokinetic tests would be correspondingly increased. It is to be regretted that the absence of a standard deviation for any of the aesthetokinetic tests, obtained from a random sample, makes it impossible to test this hypothesis. All that can be said is that if such selection has taken place, and there seems reason to think it has, then the "true" correlations with the aesthetokinetic tests would be higher than the observed ones. If these tests are put into practice it will be possible to obtain a standard deviation from a more nearly random sample, since all applicants, whether finally accepted or rejected, would be tested. When this has been done the effect of selection on the basis of aesthetokinetic co-ordination can be measured in the same way as the effect of selection on the basis of intelligence has been measured.

Whatever the causes may be for the smallness of the correlation coefficients, they are not less valuable than the higher ones obtained from other sources. It is just as important to know that two variables are slightly related in certain groups of subjects as to know that they are closely related, for both these facts will affect scientific method.

In order to see if the suggestions put forward to account for the nature of the intercorrelations between the tests held good for the linguistic intelligence tests, the five questions in the intelligence paper were intercorrelated. Questions I, II and III (opposites, analogies and mixed sentences) all involve verbal fluency in a marked degree. Question V (reasoning) depends almost entirely on syllogistic reasoning.

The mean of the intercorrelations between Questions I, II and III was ·**439,** and the mean of the correlation between Question V and I, II and III was ·**276.** It will be seen that the higher correlation is between questions involving similar verbal processes, and the lower correlation between questions involving dissimilar ones. The mean of all the intercorrelations between the five tests was ·**378,** which is lower than that usually found between different parts of an intelligence paper when the subjects are children, the coefficient in this case usually being about ·50.

These results are in agreement with the suggestions already put forward. The intercorrelation between all the tests in the intelligence paper is higher than that between the sensori-motor tests but lower than that found among children, and the tests which have a similar medium correlate in a higher degree than those with a dissimilar one, although they also have a functional factor in common.

The psychological examination of a group of subjects can be simplified and made more systematic by a proper use of the knowledge gained from these intercorrelations. It can also be adapted more definitely to a particular end. If, for instance, it is desired to examine the fundamental psychological functional reactions of a group of subjects, tests can be chosen from each of the specific groups that have manifested themselves with the relative certainty that by so doing a fairly wide range of non-intercorrelating psychological functions will be tested. Doubtless other group factors will manifest themselves as experimental work advances and other tests are devised, and by following the same method of examining their intercorrelations the range of the psychological functions that it is possible to test will be gradually increased.

If it is desired to measure psychological functions in relative isolation, the tests can be chosen from non-intercorrelating groups (e.g., the intelligence and simple aesthetokinetic tests), but if the object is to measure psychological functions in integration, then tests can be chosen from a group that is known to correlate with two other groups which do not correlate with each other. For instance, the complex aesthetokinetic tests correlate with the simple aesthetokinetic and with the intelligence tests, although the simple aesthetokinetic and intelligence tests do not correlate with each other. They therefore presumably measure two integrated psychological functions and would be useful in an examination that had this end in view, though they would not be useful in one that sought to measure psychological functions in isolation.

The correlation that has been found to exist between tests employing similar perceptual settings, in spite of a dissimilarity in other psychological factors they may involve, is corroborative evidence of the value of *analogous tests*. The object of the analogous test is prognostic rather than analytic, for it is mainly used for predictive purposes in cases where it is more important to select those who will do well in an occupation than to examine in detail the underlying psychological factors involved in success. In repetition processes, where the same movement cycles are constantly repeated, it will generally be found possible to devise tests employing similar movement cycles. If this is possible and the degree of similarity between the test medium and the medium of the occupation is sufficiently marked, then, judging by the present data, a correlation between performance in the tests and performance in the occupation should be found, irrespective of the fact that each of the tests used may involve different functional performance factors.

In the skilled occupations such as engineering, where the movements involved are too heterogeneous to make the use of analogous tests possible, the best method of devising selective tests is probably by measuring the part played by various functional performance factors in occupational success. In repetition processes, where movements are more standardised and therefore more easily imitated, better results will probably be obtained by the use of analogous tests than of tests of a more general nature. In the former case specific psychological functions should be made the basis of selection and in the latter ability to perform certain movements. Cases will, of course, arise where both methods can be profitably employed.

PART III.—Relation between the Tests and other Criteria.

INTRODUCTION.

The examination of the intercorrelations of the tests presented in Part II showed that they fell into different groups having consistent relationships with one another. In Part III the relation between the tests and the objective criteria of industrial proficiency, accident and sickness rate is examined. This examination makes it possible to see whether the groups of tests which emerged from the intercorrelations tables have consistent relations with these objective criteria. Reasons have been put forward in Part II for assuming that certain tests correlate among themselves because they measure some factor of a functional nature which is common to them all. If this point is conceded and if consistent relations are found between certain of the groups of tests and the objective criteria, then it will be possible to say not merely that certain tests correlate with certain objective criteria, but also that these criteria involve certain psychological factors, although the nature of these factors may not be known.

Consistent relationships if found between the groups of tests and the objective criteria, will show that the theoretical conclusions arrived at in Part II are of practical value in psychological analysis. Even if the results of the present investigation are not very striking, this fact will not be an indication that the method is at fault, but merely that not sufficient psychological factors have been measured to give an adequate determination of all the integrated psychological functions involved in the criteria. If the method is even partially successful in systematising the present methods of psychological analysis, it is worth pursuing until many more measurable psychological factors have been examined. The factors examined in the present investigation range from the almost purely physical (dynamometer), through the lower and higher levels of sensori-motor co-ordination, up to the higher intellectual processes, so that they may be regarded as representative of certain lines of biological development. It is, of course, obvious that many important psychological factors have been wholly omitted in this investigation, and it is not until an attempt has been made to measure these by the same method that its possibilities can be fully judged.

THE RELATION BETWEEN THE TESTS AND ACCIDENT AND SICKNESS INCIDENCE.

It will be seen at a glance from Tables XVIII and XIX that there is no relationship between any of the tests and accident and sickness rate among the R.A.F. apprentices, either as a whole or when the trades are considered separately. A positive relation between success in the aesthetokinetic tests and a low accident rate was previously found in Group IV (I.F.R.B. Report No. 38), when their accidents for the first nine months of their training period were compared with their test performances. The accidents dealt with in this report are for a period of three years, so that the results must be regarded as more reliable and accepted in preference to those previously put forward.

Table XX shows that among the Dockyard apprentices there is a small positive relationship between the simple aesthetokinetic tests (*a*, *b*, *c*), and accident rate, and also between the intelligence tests (*f*, *g*) and accident rate, though in this latter case the tests have been given to two groups only. There is no relation between any of the tests and sickness.

TABLE XVIII.—*The Correlation Coefficients between the Tests and Accident and Sickness Rates for the R.A F. Apprentices not Separated into their Different Trades.*

Test	Accidents				Sicknesses			
	Groups			Wgtd mean.	Groups.			Wgtd. mean.
	III.	IV	V.		III.	IV.	V.	
Reaction . .	—·019	—·037	—	—·025	—·024	·079	—	·010
Dotting . .	**·112**	032	—·064	·043	**·120**	·064	·071	·092
Pursuit meter	—	**104**	—	**·104**	—	**·128**	—	**·128**
Interrupted Pursuit meter	—·017	—	—	—·017	—·069	—	—	— 069
Co-ordination	·020	—	—	020	—·011	—	—	—·011
Rectangles	—	·020	—·073	—·026	—	·086	—**·114**	—·014
Strip . .	—	—·035	·023	—·006	—	·027	·004	·015
Cube . .	—	·013	—**·143**	—·065	—	—·026	—·077	—·051
Number setting	**·112**	—**·117**	—**·123**	—·003	—·008	—·088	—**·122**	—·056
Linguistic Intelligence	·048	—**·136**	—·102	—·035	—·036	—·031	—·080	—·046
Stereoscope	—	—	·087	·087	—	—	·031	·031
Dynamometer	—·063	·005	—**·150**	—·068	·017	—·010	·010	·009

TABLE XIX.—*The Correlation Coefficients between the Tests and Accident and Sickness Rates for R.A.F. Apprentices separated into Fitters and Carpenters.**

Test.	Carpenters' Groups.				Fitters' Groups			
	III	IV	V.	Wgtd. mean	III	IV	V	Wgtd mean
1. *Accidents.*								
Reaction ..	·007	—·027	—	—·013	—·054	—·052	—	—·053
Dotting ..	—·067	·043	— 025	—·007	**·173**	·025	—·069	·060
Pursuit meter	—	**·192**	—	**·192**	—	·027	—	·027
Interrupted Pursuit meter	—·011	—	—	—·011	—·004	—	—	—·004
Co-ordination	—·081	—	—	—·081	·068	—	—	·068
Rectangles	—	·049	—**·219**	—·043	—	—·011	—·046	—·032
Strip ..	—	— 053	005	—·033	—	—·013	·008	— 0005
Cube ..	—	·126	—**·263**	—·008	—	—·056	—·101	—·083
Number setting	·033	— **179**	·032	—·063	**118**	—·080	—**·167**	— 013
Linguistic Intelligence	·076	—·088	037	—·007	—·039	—·112	—·120	—·080
Stereoscope	—	—	—·130	—·130	—	—	**·140**	**·140**
Dynamometer	—·170	·029	—**·217**	— 092	—**·174**	—·011	—**·122**	—**·123**
2. *Sicknesses*								
Reaction ..	·019	·082	—	·056	—·011	—·066	—	—·028
Dotting ..	—·052	·067	—·023	·009	**·146**	—·053	·125	·094
Pursuit meter	—	·138	—	·138	—	—·126	—	—·126
Interrupted Pursuit meter	— 106	—	—	—·106	—·055	—	—	—·055
Co-ordination	— 099	—	—	—·099	·033	—	—	·033
Rectangles	—	·074	—**·204**	—·021	—	—·103	—·087	—·093
Strip ..	—	·011	·092	·039	—	—·026	—·018	—·021
Cube ..	—	—·039	—·162	—·081	—	·031	—·031	—·006
Number setting	—·074	—·096	—·175	—·108	—·014	·061	—·099	—·025
Linguistic Intelligence	—·096	—·010	—·132	—·066	—·077	—·021	—·067	—·062
Stereoscope	—	—	·036	·036	—	—	·032	·032
Dynamometer	·050	·095	—·047	·047	—·010	·059	·044	·022

* Certain other trades besides carpenters and fitters were represented among the R.A F. apprentices, but the numbers employed in each group were too small for satisfactory statistical treatment. The only trades that will be considered separately in this report will therefore be carpenters and fitters.

TABLE XX.—*Correlation Coefficients between the Tests and Accidents and Sicknesses for the Dockyard Apprentices.*

Test.	Group.	Accidents.		Sicknesses.	
		*Q5s.	*r.s.	Q5s.	r.s.
a Reaction ..	VI	·087	·001	·055	·051
	VII	**·200**	**·222**	**·281**	·095
	VIII	—**·216**	—	·141	—
	IX	**·435**	—	—·171	—
	Wtd mean	·109	—	·101	—
b Dotting	VI	**·238**	·172	—**·287**	—·199
	VII	**·300**	·190	**·249**	—·049
	VIII	·136	—	—·063	—
	IX	—·049	—	·060	—
	Wtd mean	·165	—	·021	—
c Pursuit meter ..	VI	·209	·213	·144	—·132
	VII	**·454**	·091	—·067	—·022
	VIII	—·012	—	·023	—
	IX	—	—	—	—
	Wtd mean	**·224**	—	015	—
d Interrupted Pursuitmeter.	VI	—	—	—	—
	VII	—	—	—	—
	VIII	—	—	—	—
	IX	—·029	—	·183	—
	Wtd. mean	—·029	—	·183	—
e. Co-ordination ..	VI	—	—	—	—
	VII	—	—	—	—
	VIII	—	—	—	—
	IX	—·127	—	—·074	—
	Wtd mean	—·127	—	—·074	—
f Number setting..	VI	—	—	—	—
	VII	—	—	—	—
	VIII	·167	—	**·209**	—
	IX	·008	—	**·315**	—
	Wtd. mean	·099	—	**·254**	—
g Linguistic Intelligence	VI	—	—	—	—
	VII	—	—	—	—
	VIII	·159	—	·117	—
	IX	·087	—	·009	—
	Wtd mean	·128	—	·071	—
h Dynamometer ..	VI	—	—	—	—
	VII	—	—	—	—
	VIII	—	—	—	—
	IX	·011	—	—·037	—
	Wtd. mean	·011	—	—·037	—
i. Steadiness ..	VI	—	—	—	—
	VII	—	—	—	—
	VIII	—	—	—	—
	IX	**·241**	—	—·106	—
	Wtd. mean	**·241**	—	—·106	—

* Q5 is the coefficient obtained by the four-fold method, and r the coefficient obtained by the product-moment method. *See* footnote on p. 57.

COMPARISON OF THE ACCIDENT AND SICKNESS RECORDS OF THE R.A.F. AND DOCKYARD APPRENTICES.

The fact that there appears to be a relation between the aesthetokinetic tests, and possibly the intelligence test, and accidents among the Dockyard apprentices, while there is no relation between any of the tests and accidents among the R.A.F. apprentices necessitates an examination of the accident records from both sources to see if they differ in any respect. Both sets of apprentices are employed in skilled trades very similar in nature ; they are also about the same age and the same social and intellectual standing. The R.A.F. apprentices are probably superior physically, but not to a very marked degree. The main difference between the two is that the R.A.F. apprentices are living a barrack life whereas the Dockyard apprentices are living at home and are employed on a purely industrial basis. The accident records of the R A.F. apprentices contain accidents sustained outside the workshop when the boys are at play or in the barracks. The accident records of the Dockyard apprentices contain only the accidents sustained during working hours. The causes of non-industrial accidents may be different from those of industrial accidents, and their inclusion in the records may mask the relation that may possibly exist between the tests and industrial accidents. Probably the greatest source of error that arises by their inclusion is that the factor of exposure to accident risk is thereby made unequal. The boy who takes his exercise by playing football regularly is probably more likely to sustain accidents than the boy who takes his exercise by cross country running, and the boy who is given to boisterous games in the barrack room (a fruitful source of minor accidents) is more likely to sustain injury than the boy who employs his leisure in reading or playing sedentary games. There is no possible means of keeping exposure constant if industrial and non-industrial accidents are not separable.

Again lost time on account of accidents or sickness involves no financial loss to the R.A.F. apprentices, whereas it does to the Dockyard apprentices.

It is clear from internal and external evidence that the accident and sickness records of the R.A.F. apprentices are less appropriate for statistical analysis than those of the Dockyard apprentices. The lack of relationship between the tests and accident rate among the R.A.F. apprentices therefore does not indicate that there is no relation between the tests and *real* accident proneness, but only that there is no relation between the tests and accident records which are known to be affected by definite sources of error.

Finally, the method of keeping the accident records in the Dockyard made it perfectly easy to distinguish between an original accident and subsequent visits to the sick bay connected with the same accident for purposes of redressing or medical examination. The method of keeping the R.A.F. records made it very difficult to distinguish between an original accident and subsequent visits to the hospital connected with the same accident. When copying the records every effort was made to distinguish between the two, but it was recognised at the time as a definite source of error which it was impossible wholly to eliminate.

TABLE XXI.—*The Average Accident and Sickness Rates per Man per Year for the R.A.F. and Dockyard Apprentices.*

	Group.	Accidents.	Sicknesses.
R A F. apprentices . .	III	723	2 287
	IV	772	2 004
	V	654	4·268
Dockyard apprentices	VI	452	·219
	VII	·390	·223
	VIII	·564	·218
	IX	·429	·200

The average accident and sickness rates for the R.A.F. and Dockyard apprentices are given in Table XXI. The slightly higher accident rate of the R A.F. apprentices is probably due to the fact that it was impossible to distinguish in the records between an original accident and subsequent visits to hospital in connection with the same accident, and also to the inclusion of non-industrial accidents. It should not be taken as an indication that the *real* accident rate is higher than in the dockyard. The difference in the sickness rate of the two groups is too great (being ten times greater among the R.A.F. than among the Dockyard apprentices) to be accounted for wholly on this basis and suggests that there is a certain amount of malingering among the R.A.F. apprentices. The medical authorities in charge of the boys recognise this and do what they can to combat it, but no means they can employ are adequate to deal with the abuse as long as absence from work through sickness involves no disadvantage of an obvious kind.

Figures 1 and 2 show the yearly accident and sickness curves of the two sets of apprentices. The rapid drop in accident rate among the Dockyard apprentices as training proceeds may be a genuine sign of an increase in motor dexterity, or it may imply that the standard of reporting accidents tends to become less strict as the boys' earnings increase and the subsequent financial loss due to lost time is correspondingly greater. The opposite tendency in the R.A.F. apprentices could be accounted for by assuming that the standard of reporting minor injuries tended to become more strict, or the number of redressings tended to increase as it was realised more and more that no disadvantage accrued to them by so doing.

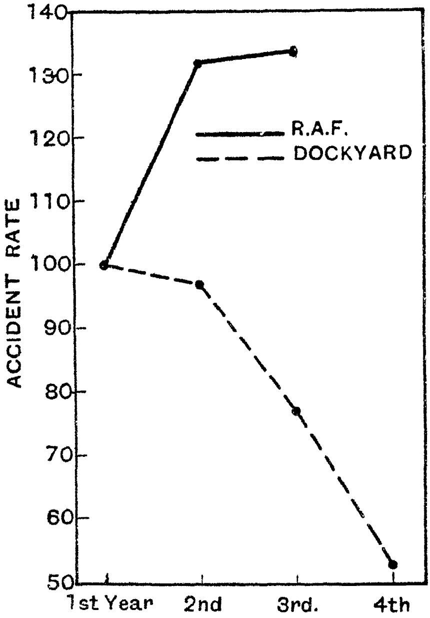

FIGURE 1.

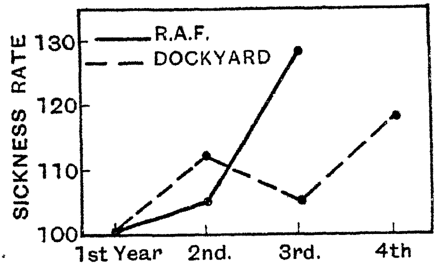

FIGURE 2.

In these curves the first year's sickness and accident rate are taken as 100 and subsequent years' averages are expressed as percentages of this.

The sickness rate of both groups tends to rise as training proceeds, but the percentage rise is greater among the R.A.F. than among the Dockyard apprentices.

The difference in the reliability of the accident and sickness records of the Dockyard and R.A.F. apprentices having been been noted consideration of the relations between the tests and accidents and sicknesses will be postponed until their relationship with industrial proficiency has been examined, since an examination of this relationship yields conclusions which will facilitate the subsequent presentation of the data of the relation between the tests and accident proneness.

THE RELATION BETWEEN THE TESTS AND INDUSTRIAL PROFICIENCY.

It was impossible to obtain proficiency records for the Dockyard apprentices, but very full records were obtained for the R.A.F. apprentices, each boy being examined practically and theoretically before being passed out of the training centre. The passing out assessments are composed of the following items:—

Local Technical Marks.—After a year's training the apprentices are given a practical examination by their own officers and the marks assigned in this examination are known as the Local Technical marks.

Central Trade Test Board.—At the end of the three-year period of training the boys are examined by the Central Trade Test Board composed of technical R.A.F. officers who visit the camp for the purposes of examination and are not connected with the boys' training in any other respect. The examination consists of doing a practical piece of work and answering verbal questions relating to the technique of the particular trade in which the apprentice has been trained.

General Efficiency.—The officers in charge of the apprentices in the barracks assign to each boy a mark for general efficiency. This mark is given as a result of close observation of the boys' conduct in the barracks over a period of three years, and smartness, cleanliness and good behaviour are the qualities looked for.

School Marks.—At the end of the training period a written technical and general examination is given, and the marks gained in this are known as the School marks.

The Final Passing-out order is composed of marks obtained from these various measures of proficiency, the total number of marks it is possible to gain from each measure being:—

Local technical	100
C.T.T.B.	400
General efficiency	200
School marks	400
Total	1,100

TABLE XXII.—*The Correlation Coefficients between the Tests and the Passing-out Results for the R.A.F. Apprentices not separated into Trades.*

Test.	Groups	School Marks.	Local Tech.	General Effic	C.T.T.B.	Total.
(*a*). Reaction time	III	**·112**	·062	**·119**	**·075**	**·135**
	IV	**·174**	**·212**	**·146**	**·161**	**·207**
	V	—	—	—	—	—
	Wtd. mean	**·133**	**·112**	**·128**	**·104**	**·159**
(*b*). Dotting	III	·054	·073	**·143**	**·125**	**·128**
	IV	·045	**·104**	**·155**	·053	**·117**
	V	**·195**	**·221**	**·095**	**·131**	**·205**
	Wtd mean	·095	**·126**	**·131**	**·110**	**·149**
(*c*). Pursuit meter	III	—	—	—	—	—
	IV	·053	·101	**·105**	·052	·086
	V	—	—	—	—	—
	Wtd. mean	·053	·101	**·105**	·052	·086
(*d*). Interrupted Pursuit meter	III	**·153**	**·085**	**·100**	**·133**	**·171**
	IV	—	—	—	—	—
	V	—	—	—	—	—
	Wtd mean	**·153**	**·085**	**·100**	**·133**	**·171**
(*e*). Co-ordination.	III	**·150**	**·129**	**·092**	**·195**	**·190**
	IV	—	—	—	—	—
	V	—	—	—	—	—
	Wtd mean	**·150**	**·129**	**·092**	**·195**	**·190**
(*f*).Rectangles	III	—	—	—	—	—
	IV	·047	·089	—·033	·096	·074
	V	·087	·011	·044	**·136**	**·122**
	Wtd mean	·070	·045	·011	**·119**	·101
(*g*) Strip ..	III	—	—	—	—	—
	IV	·047	·008	—·014	—·044	·005
	V	·048	—·018	—·018	·052	·023
	Wtd mean	·048	—·007	—·016	·011	·015
(*h*). Cube ..	III	—	—	—	—	—
	IV	**·297**	**·323**	·079	**·259**	**·296**
	V	**·259**	**·235**	·079	**·227**	**·273**
	Wtd. mean	**·275**	**·270**	·079	**·241**	**·283**
(*i*). Number setting	III	**·128**	**·080**	·027	**·094**	**·114**
	IV	·055	·040	—·027	·030	·025
	V	·089	·089	·063	**·097**	**·106**
	Wtd. mean	·099	·074	·026	·080	·091

TABLE XXII.—*The Correlation Coefficients between the Tests and the Passing-out Results for the R.A.F. Apprentices not separated into Trades*—continued.

Test.	Groups.	School Marks	Local Tech	General Effic.	C.T T.B	Total.
(*k*) Linguistic Intelligence	III	**·398**	**·173**	**·102**	**·124**	**·288**
	IV	**·455**	**·153**	·048	**·110**	**·289**
	V	**·409**	**·247**	**·104**	**·216**	**·336**
	Wtd mean	**·415**	**191**	090	**·149**	**·303**
(*l*) Stereoscope	III	—	—	—	—	—
	IV	—	—	—	—	—
	V	**161**	**·095**	**·126**	**·146**	**·204**
	Wtd mean	**·161**	**·095**	**·126**	**·146**	**·204**
(*m*) Dynamometer	III	·034	**·075**	**203**	**·094**	**·122**
	IV	·060	·095	**·181**	**·144**	**·148**
	V	**·167**	**·162**	**·130**	**·108**	**·175**
	Wtd. mean	·081	**·106**	**·176**	**·110**	**·144**

The chief features to note in this table are ·—

1. The number setting test (*i*) does not correlate with the passing-out records with the same consistency as do the other intelligence tests (*a*, *b*).

2. The other two intelligence tests (*k*, *h*) yield the highest correlations with the school marks of any of the tests, and they also correlate with local technical marks and C.T.T.B. marks, though not with general efficiency.

3. There is on the whole a small positive correlation between the simple aesthetokinetic tests (*a*, *b*, *c*) and all the passing-out results except school marks. The fact that choice reaction correlates with school marks whereas the other two do not is probably due to its correlation with intelligence already referred to.

4. The complex aesthetokinetic tests (*d*, *e*) and also the stereoscopic test tend to correlate with all the passing-out results, although as they have only been given once no conclusion can be be drawn from them.

5. The form perception tests (*f*, *g*) do not correlate consistently with any of the passing-out records.

6. The dynamometer test (*m*) tends to correlate with all the passing-out records except school marks.

TABLE XXIII.—*The Correlations between the Tests and the Passing-out Scores for R.A.F. Apprentices Separated into Trades.*

Test		School Marks		Local Technical		General Efficiency		C T T B		Total	
	Groups	Fitters	Carps	Fitters	Carps	Fitters	Carps	Fitters	Carps	Fitters	Carps
Reaction	III	**·171**	029	088	108	**154**	**·206**	021	**217**	**151**	170
	IV	**287**	**179**	**253**	162	**179**	115	170	145	**265**	**157**
	V										
	Wtd mean	**207**	117	140	140	**·162**	152	068	175	**187**	**·162**
Dotting	III	022	— 026	101	113	**137**	**198**	**150**	067	**137**	032
	IV	082	015	096	113	114	**194**	077	090	109	111
	V	**234**	029	**296**	017	**·196**	— 042	**152**	063	**267**	020
	Wtd mean	117	008	**176**	083	**155**	122	**136**	078	**182**	061
Pursuit meter	III	—	—	—	—	—	—	—	—	—	—
	IV	131	— 083	075	123	·136	091	— 003	127	·117	033
	V										
	Wtd mean	131	— 083	·075	123	136	091	— 003	127	117	033
Interrupted Pursuit meter	III	**241**	010	**162**	— 047	**203**	0002	**221**	— 023	**279**	— 001
	IV	—	—	—	—	—	—	—	—	—	—
	V	—	—	—	—	—	—	—	—	—	—
	Wtd mean	**241**	010	**162**	— 047	**203**	0002	**221**	— 023	**279**	— 001
Co-ordination	III	109	090	**165**	**314**	·034	**293**	**235**	171	**173**	**·227**
	IV	—	—	—	—	—	—	—	—	—	—
	V	—	—	—	—	—	—	—	—	—	—
	Wtd mean	·109	090	**165**	**314**	034	**293**	**235**	171	**173**	**227**
Rectangles	III	—	—	—	—	—	—	—	—	—	—
	IV	035	112	— 060	**241**	011	— 065	— 011	**184**	011	130
	V	**127**	086	**118**	— 024	081	131	**227**	137	**160**	135
	Wtd mean	096	101	·057	·128	057	019	145	164	·109	132
Strip	III	—	—	—	—	—	—	—	—	—	—
	IV	021	044	004	·019	— 007	— 020	006	— 077	002	001
	V	**170**	— **195**	**123**	— 060	045	— 123	102	— 085	**129**	— 158
	Wtd mean	·119	— 058	082	—·015	027	— 064	069	— 080	085	— 067
Cube	III	—	—	—	—	—	—	—	—	—	—
	IV	**351**	**312**	**359**	**288**	**·185**	— 027	**280**	**243**	**357**	**225**
	V	**310**	063	**243**	**173**	043	018	**237**	**176**	**319**	079
	Wtd mean	**324**	**206**	**283**	**204**	092	— 008	**252**	**·214**	**332**	**163**
Number setting	III	060	126	021	**200**	014	115	**117**	**204**	088	161
	IV	**·168**	035	125	— 052	— 033	— 023	126	— 090	105	— 030
	V	·096	011	084	072	**119**	023	103	·079	**136**	031
	Wtd mean	·095	054	065	058	044	031	·114	046	109	043
Linguistic Intelligence	III	**228**	**459**	066	**199**	044	131	064	**216**	**155**	**331**
	IV	**363**	**·398**	**245**	132	034	079	**210**	**171**	**296**	**·234**
	V	**482**	121	**242**	089	**177**	001	**·246**	117	**409**	086
	Wtd mean	**350**	**331**	**167**	138	092	070	**161**	**167**	**277**	**217**
Stereoscope	III	—	—	—	—	—	—	—	—	—	—
	IV	—	—	—	—	—	—	—	—	—	—
	V	**193**	079	**138**	129	**207**	**245**	**151**	152	**242**	154
	Wtd. mean	**193**	079	**138**	129	**207**	**·245**	**151**	152	**·242**	154
Dynamometer	III	·016	049	·093	129	**·170**	**·269**	012	067	063	131
	IV	026	·122	005	**·186**	·124	**236**	**148**	**157**	088	**183**
	V	**·129**	— 013	**·190**	— 013	**236**	033	**·153**	— 032	**223**	006
	Wtd mean	060	060	112	109	**186**	**·184**	·091	074	·128	·114

It will be seen from Table XXIV that in no case where the evidence is sufficient to draw any conclusions is the relation between any of the tests markedly different for the two trades. None of the tests can, therefore, be used for determining which trade a boy should enter since they only measure functions involved in both trades.

TABLE XXIV.—*The Correlation Coefficients between the Entrance Examinations and the Passing-out Results for the R.A.F. Apprentices.*

	Groups.	School Marks	Local Tech.	General Effic.	C.T.T.B.	Total.
Nomination	III	**·572**	**·286**	**·221**	**·181**	**·424**
	IV	**·605**	·075	—·038	—·106	**·222**
	V	**·557**	**396**	**·148**	**·170**	**·387**
	Wtd. mean	**·576**	**·267**	**·140**	·111	**·367**
Open and Service	III	**·558**	**·234**	**·245**	**·156**	**·410**
	IV	**·534**	·146	·095	·091	**·312**
	V	**·674**	**·436**	**·347**	**·452**	**·516**
	Wtd. mean	**·595**	**·289**	**249**	**·250**	**·427**

The Relation between the Entrance Examination and the Final Examination.

The entrance of boy apprentices to the R.A.F is dependent upon a written examination which they must pass prior to their medical examination by the R.A.F. Medical Staff. For nomination candidates the examination is conducted by a board of examiners appointed by the R.A.F. For open and service candidates the examination is conducted by the Civil Service Commissioners. The syllabus for both examinations is the same and comprises mathematics, science, English composition, and a general paper. The two examinations are treated separately in the table since the method of presenting the results in slightly different in the two cases, although the examinations are regarded as being of equal difficulty.

It will be seen from Table XXIV that the highest correlations in all groups are between the entrance examination and school marks. This is to be expected since it is a correlation between two written examinations dealing with similar subjects separated by a period of training, and is evidence that initial intellectual or scholastic ability correlates with capacity for developing it. The other correlations are not markedly superior to those found to exist between certain of the psychological tests and the passing-out records.

Table XXV shows that there is no consistent correlation between any of the tests and the entrance examinations except in the case of the intelligence and cube tests (*k*, *h*). Since the other tests do not correlate with the entrance examinations any relationship that they have with the final measure of proficiency will be independent of any relationship the entrance examinations may have with the passing-out results. The aesthetokinetic tests (*a*, *b*, *c*), the intelligence tests (*h*, *i*, *k*) and the dynamometer test (*m*) have already been shown not to intercorrelate.

TABLE XXV.—*Correlation Coefficients between the Tests and the Entrance Examinations.*

Test.	Groups.	Nomination.	Open and Service.
a. Reaction time .	III	·058	062
	IV	—·047	—·089
	V	—	—
	Wtd. mean ..	·024	·008
b. Dotting . .	III	·056	—·034
	IV	·003	— 098
	V	**·203**	**·219**
	Wtd. mean ..	·084	·045
c. Pursuit meter ..	III	—	—
	IV	·051	003
	V	—	—
	Wtd mean .	051	003
d. Interrupted Pursuit meter	III	·045	·078
	IV	—	—
	V	—	—
	Wtd. mean ..	·045	·078
e. Co-ordination .	III	—·064	**·173**
	IV	—	—
	V	—	—
	Wtd. mean ..	—·064	**·173**
f. Rectangles ..	III	—	—
	IV	·017	·046
	V	·003	—·043
	Wtd mean ..	·009	—·009
g. Strip	III	—	—
	IV	·086	·039
	V	·102	—·110
	Wtd. mean ..	·095	—·053
h. Cube	III	—	—
	IV	·054	**·210**
	V	**·259**	**·148**
	Wtd. mean ..	·165	**·172**
i. Number setting ..	III	·080	**·168**
	IV	·018	—·086
	V	·085	—·078
	Wtd. mean ..	·067	·002

TABLE XXV.—*Correlation Coefficients between the Tests and the Entrance Examinations*—continued.

Test.	Groups	Nomination	Open and Service
k Intelligence ..	III IV V	**·364** **·457** **·393**	**·336** **·373** **·437**
	Wtd mean .	**·394**	**·384**
l. Stereoscope ..	III IV V	— — ·063	— — ·106
	Wtd mean .	063	·106
m Dynamometer .	III IV V	—·022 — 061 **232**	·002 ·032 ·019
	Wtd. mean .	·039	·015

RELATION BETWEEN THE TESTS AND PRACTICAL MEASURES OF PROFICIENCY.

Since four-elevenths of the passing-out total of the R A.F. apprentices is composed of a written examination in many respects similar to their entrance examination, it is clear that any correlation between the entrance examination and the final total marks must to a large extent be due to the correlation which must naturally exist between the results of the same tests given at different periods. That this is the case can be seen in Table XXIII in which the correlations between the entrance examination and school marks are far higher than those between the entrance examination and the passing-out total.

In order to make the psychological tests and the entrance examination strictly comparable it was decided to get a new measure of proficiency which should contain no element of either of them. This was done by adding together the local technical, C.T.T.B., and general efficiency scores in the same proportion as they appeared in the passing-out total, i.e., 100, 400 and 200 marks respectively, making a total of 700 marks. This score was called *practical total*, and the correlations it gave with the psychological tests and the entrance examinations are shown in Table XXVI. The relations between the tests and the practical total are of the same degree as those between the tests and the passing-out total, the separate trades likewise manifesting no distinct differences. The correlations between the entrance examinations and the practical total, however, are considerably lower than those between the entrance examinations and the passing-out total.

TABLE XXVI.—*Coefficients of Correlations between Practical Total and the Tests and Entrance Examinations.*

Test	ALL SUBJECTS				FITTERS				CARPENTERS.			
	Groups			Wted mean	Groups			Wted mean	Groups			Wted. mean
	III	IV	V		III	IV	V		III	IV	V	
Linguistic Intelligence	**139**	**107**	**·249**	**165**	066	**168**	**282**	**·167**	**222**	**·161**	079	**153**
Cube	—	**244**	**234**	**238**	—	**308**	**257**	**·275**	—	**183**	095	·145
Number setting	**085**	0004	**099**	070	094	077	**116**	·099	**·192**	− 090	042	031
Reaction	**095**	**189**	—	**126**	078	**226**	—	**·124**	**190**	134	—	**·157**
Dotting	**133**	**148**	**177**	**·151**	**155**	142	**221**	**178**	075	**·169**	022	098
Pursuit meter	—	103	—	·103	—	073	—	073	—	138	—	138
Co-ordination	**191**	—	—	**191**	**198**	—	—	**198**	**·218**	—	—	**218**
Interrupted Pursuit meter	**142**	—	—	**142**	**249**	—	—	**249**	− 027	—	—	− 027
Rectangles	—	057	**118**	092	—	− 023	**144**	087	—	122	160	138
Strip	—	− 032	024	00009	—	− 002	096	062	—	− 051	− 073	− 060
Stereoscope	—	—	**201**	**201**	—	—	**228**	**228**	—	—	133	·133
Dynamometer	**162**	**177**	**173**	**169**	·091	**150**	**223**	**152**	156	**212**	− 009	·129
Nomination	**245**	− 072	**227**	**·166**	**194**	− 056	**228**	**156**	**·348**	**214**	− 008	**187**
Open and Service	**229**	·121	**348**	**248**	**205**	**362**	**289**	**273**	**339**	111	**437**	**·284**

It will be possible henceforth to deal with two final measures of industrial proficiency among the R.A.F. apprentices. *Total passing out* will include practical and theoretical ability, *practical total* will include practical ability only. It may be argued that theoretical ability for an R.A.F. apprentice is not an end in itself, but only a means to an end. Without expressing any views as to the validity of this opinion, by distinguishing between the practical and theoretical abilities the value of the psychological tests from either point of view can be judged.

WEIGHTING.

1. *Total passing-out score.*

If linguistic intelligence, cube and the entrance examinations be formed into one group, the aesthetokinetic tests into another, and the dynamometer be regarded as the sole representative of a third group, three non-intercorrelating measures of ability are obtained, each one of which correlates independently with final proficiency. (By assuming the equality of the two entrance examinations and expressing the scores of each as percentages of their means, one entrance score was obtained for all the subjects in each group.) A single score was first obtained for each of the three groups of tests by weighting each member of the group according to its relation with proficiency, as measured by its regression coefficient on the total passing-out score.* This process was, of course, necessary only in the case of the intelligence and aesthetokinetic groups, since dynamometer stood alone The weights for the intelligence group were, entrance examination 2, linguistic intelligence 1, and cube 1; and for the aesthetokinetic group, reaction time 11, dotting 5, and pursuit meter 1. The three scores so obtained were then correlated with the passing-out total, yielding the following correlation coefficients :—

Intelligence ..	Group III	**·449**	Weighted mean **·444.**
	IV	**·398**	
	V	**·470**	
Aesthetokinetic	III	**·183**	Weighted mean **·194.**
	IV	**·201**	
	V	**·205**	
Dynamometer	III	**·122**	Weighted mean **·144.**
	IV	**·148**	
	V	**·175**	

These three scores were then combined into a single final score by weighting each according to its relation with proficiency. The weights used were: the intelligence group 7, the aesthetokinetic group 3, and the dynamometer 2. The final combined score obtained in this way was correlated with both the passing-out total and the practical total, giving the following correlation coefficients :—

Group.	*Passing-out Total.*	*Practical Total.*
III	**·486**	**·308**
IV	**·430**	**·202**
V	**·483**	**·368**
Weighted mean ..	**·472**	**·302**

2. *Practical total.*

The same tests were then combined with the entrance examination a second time using as a basis of weighting their relation with practical total. In this case the weights were: in the intelligence group, entrance examination 8, linguistic intelligence 5, and cube 9; in the aesthetokinetic group, reaction time 16, dotting 13, and pursuit meter 5; and for the groups themselves: the

---

[*] The weights used are given by the regression coefficients in the regression equation of proficiency on the tests. The general regression equation of x_0 (proficiency) on $x_1, x_2, x_3 \ldots . x_n$, is

$$
\begin{aligned}
(x_0-\bar{x}_0) &= r_{01\cdot23\ldots n}\cdot\frac{\sigma_{0\cdot23\ldots n}}{\sigma_{1\,23\ldots n}}(x_1-\bar{x}_1)\\
&+ r_{02\cdot34\ldots n\cdot1}\frac{\sigma_{0\,34\ldots n\cdot1}}{\sigma_{2\cdot34\ldots n\,1}}(x_2-\bar{x}_2)\\
&+ \text{etc.}\\
&+ r_{0n\cdot12\ldots\overline{n-1}}\frac{\sigma_{0\cdot12\ldots\overline{n-1}}}{\sigma_{n\cdot12\ldots\overline{n-1}}}(x_n-\bar{x}_n)
\end{aligned}
$$

The actual weights used are proportional to the coefficients of the x's on the right of the above equation.

intelligence group 3, the aesthetokinetic group 2, and the dynamometer 2. The coefficients obtained by correlating the final combined score thus calculated with the passing-out total and the practical total were as follows :—

Group.	*Passing-out Total.*	*Practical Total.*
III	·466	·322
IV	·456	·310
V	·436	·358
Weighted mean ..	·454	·330

When the entrance examination alone is correlated with passing-out total and practical total the coefficients are ·388 and ·195 respectively, so that it will be observed that the relations between the final combined score and the measures of proficiency are higher than those between the entrance examination alone and the proficiency records, whichever basis for weighting is adopted.

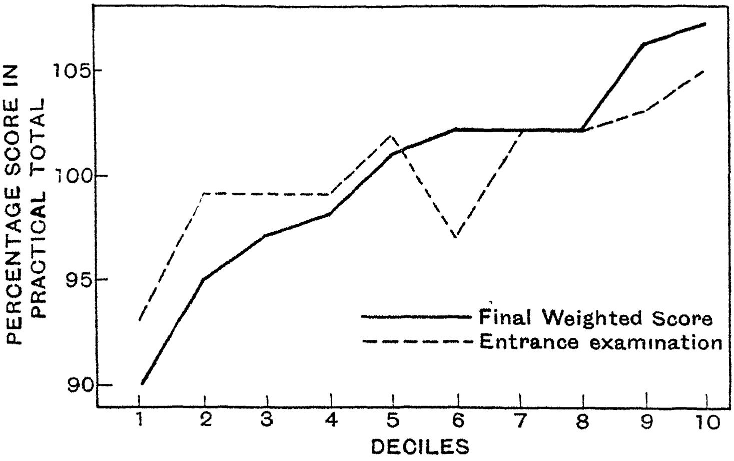

FIGURE 3.

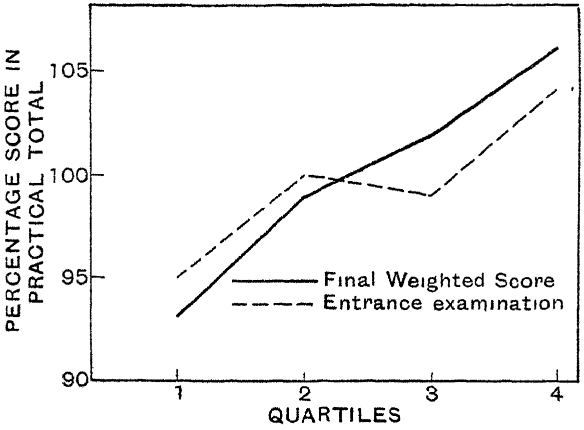

FIGURE 4.

FIGURES III and IV. Comparison of the means of practical total for the deciles and quartiles in final weighted score and entrance examination.

A graphic presentation of the differences between the prognostic value of the entrance examination of the R.A.F. apprentices and that of the final weighted score is given in Figures 3 and 4. The broken line in Figure 3 shews the average score in Practical Total of each decile in the entrance examination, and the unbroken line shews the average score in Practical Total of each decile in the final weighted score. It will be seen that in the top five deciles the industrial proficiency of those selected by the final weighted score is in every case better than that of those selected by the entrance examination alone In the bottom five deciles the industrial proficiency of those ranked by the final weighted score is in all cases worse than the mean, while for those ranked by the entrance examination alone it is in one case better.

The same results are given in Figure 4, but the curves represent quartiles instead of deciles. It will be seen that the top quartiles of the final weighted score are better and the bottom quartiles worse than the mean in industrial proficiency, whereas the same consistency is not shewn when selection is by the entrance examination alone. In both figures the curves representing the final weighted score are smoother than those representing the entrance examination, shewing that their prognostic value is more reliable than that of the entrance examination alone.

It is clear from the above figures that if the entrance examination of the R.A.F. candidates had been supplemented by the psychological tests suggested, the candidates that would have been selected in this way would tend to be more proficient than those selected by the entrance examination alone, and similarly those that would have been rejected would tend to be less proficient than those rejected by the entrance examination alone.

3. *Accidents.*

The above weighting by proficiency was carried out for the R.A.F. apprentices. A further weighting, by accidents, was done for the dockyard apprentices. In this case only groups VI and VII, with four and three years' accidents respectively, were considered, in order to avoid using fourfold correlations for purposes of weighting, and the aesthetokinetic tests were the only ones applied to these two groups of subjects.* Since the entrance records of the dockyard apprentices were presented in the form of a ranking, the test scores were also ranked and the correlations worked out by the usual ranking method.*

---

* The fourfold method of correlation (Q5) is an approximate measure of the relationship between two variables to be resorted to only in special cases where the data render the use of the product-moment method inadvisable. It is used in the case of Groups VIII and IX where the range of accidents is so small that the distribution is insufficient for the purposes of correlation by the product-moment method. This way of presenting the data is not regarded as final, for it will be dealt with again with more exact methods when a sufficient lapse of time has allowed the accident records of these groups to be completed Since the fourfold method of correlation is only an approximate measure of relationship, to use correlations thus obtained for the purposes of weighting is to build a superstructure of statistical theory upon an unreliable basis. An attempt was made to weight by means of Q5s, but since these tended on the whole to be greater than r's, far too optimistic results were obtained by this method and it was therefore abandoned, lest a false impression of the relation between the aesthetokinetic tests and accidents might thereby be given, based as it was upon meagre evidence (For Formula used see p. 67).

The weights for the aesthetokinetic tests among the dockyard apprentices were · for reaction time 1, for dotting 2, and for pursuit meter 3, and the combined aesthetokinetic score correlated with the accident records as under :—

Group VI	**·344**
VII	**·257**
Weighted mean	**·289**

The aesthetokinetic group was then combined with the entrance examination, the weights used being 1 in each case. The correlation of the final weighted score thus obtained with accidents was **·424** and **·396** in the two groups of subjects, giving a weighted mean correlation of **·406.** From Table XXIX (Appendix I) it will be seen that the weighted mean correlation between accidents and the entrance examination alone for the dockyard apprentices was **·294,** thus showing that there is a higher correlation between accidents and the final weighted score than between accidents and the entrance examination alone.

4. *Tests weighted by industrial proficiency applied to accident rate.*

In order to see the relationship between accident rate and tests weighted by industrial proficiency, the tests weighted by the passing-out total of the R.A.F. apprentices were correlated with accident rate for the dockyard apprentices. All four groups of dockyard apprentices with accident records were used and the fourfold method of correlation was employed, as the accident range was small in two of the groups. The correlations between accidents and the final weighted score worked out in this way were as follows :—

Group VI	·140
VII	**·500**
VIII	**·596**
IX	**·415**
Weighted mean	**·446**

This weighted mean coefficient should be compared with the correlation of **·294** between accidents and the entrance examination alone which was also obtained by the fourfold method.

This is evidence that these particular tests when weighted with a view to increasing industrial proficiency also have the effect of lessening accident rate. It is also evident that the weights obtained from one group of subjects are applicable to another. Since the tests weighted by industrial proficiency correlate with accident rate where the accident records are reliable, it may be assumed that if the accident records of the R.A.F. apprentices were equally reliable the correlation between the weighted tests and accident rate would be similar to that found among the dockyard apprentices.

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* See Appendix 6.

THE PRACTICAL USE OF THE WEIGHTED SCORE FOR SELECTIVE PURPOSES.

Greenwood, Yule and Newbold have shown that the distribution of accidents is a skew one, yielding a J-shaped curve. This means that a large proportion of any group sustains no accidents at all or very few, and a relatively small proportion sustains a large number of accidents, so that a high percentage of the total number of accidents in any group are incurred by comparatively few members of the group. The accident distribution of every group of subjects in the present investigation conforms to this type and agrees with the original conclusions of the above investigators.

In order to see how far the tests used in this investigation would serve as a practical means of detecting the accident prone, the four groups of dockyard apprentices were ranked (1) according to their weighted aesthetokinetic score, and (2) according to their combined weighted aesthetokinetic and entrance examination score. Each group was then divided into quartiles and the accident rate of the worst quartile compared with the accident rate of the remaining three quartiles. Weighting the groups by the numbers of subjects in them and combining them into one group, the following results emerged :—

(1) Ranking by weighted aesthetokinetic score.
Accident rate of worst quartile = ·73 per man per year.
Accident rate of remainder = ·37 per man per year.

(2) Ranking by combined weighted aesthetokinetic and entrance examination.
Accident rate of worst quartile = ·88 per man per year.
Accident rate of remainder = ·34 per man per year.

Expressed differently, the above figures mean that the worst 25 per cent. of the dockyard apprentices, as measured by the aesthetokinetic tests, have an accident rate approximately *twice* that of the remaining 75 per cent., and when measured by the aesthetokinetic tests and the entrance examination, approximately *two-and-a-half* times that of the remaining 75 per cent. Hence, if 25 per cent. of the apprentices had been rejected by their failure in the selective tests suggested, a group of boys would have been eliminated whose accident rate was more than twice as great as that of the successful apprentices.

The results obtained from the R.A.F. apprentices show that boys who do well in these same tests also tend to be more proficient in occupations very similar to those of the dockyard apprentices. If these tests were put into practice it may be presumed that they would have the effect not only of rejecting a small number of boys with a high accident rate, but also of selecting a large number of boys who on the whole would be more industrially proficient than those rejected.

CONCLUSION.

The general conclusions to be drawn from the work presented in this report are of a two-fold nature. In Part II certain theoretical conclusions bearing on the interaction of psychological functions are drawn. In Part III these conclusions have been put to the practical test, and wherever it has been possible to get valid objective criteria the particular qualities measured by certain of the tests have been shown to play a part in industrial proficiency and accident proneness.

The significant correlation coefficients presented in Part III are small, being of about the same magnitude as those presented in Part II. The same reasons that have been advanced to account for the smallness of the intercorrelation coefficients are equally valid in respect to correlations between the tests and the objective criteria of industrial proficiency and accident rate. The small correlations between the tests and the objective criteria serve to indicate that industrial proficiency and accident proneness are dependent on many dominant factors and not upon one predominant factor. Even when the tests are weighted they fail to give correlations of sufficient magnitude to warrant the assumption that they measure more than a portion of the factors involved in the objective criteria. It is clear that they measure some of the dominant factors, but there is no evidence that they measure the most important of them. This can only be determined by further experiment, and it is not claimed that the investigation has reached its final stage nor that the correlations already obtained indicate the limits of the methods employed. Other psychological factors can be measured by the method indicated in Part II, and the role played by these in the psychological functions involved in the objective criteria of industrial proficiency and accident proneness determined. Should positive results be obtained by the examination of other psychological factors, the range of operative functions will be extended, and by including them in the final assessment the correlation between the combined tests and the objective criteria will tend to increase. In the meantime, as shown on pages 56 to 58, there is evidence that even at the present stage the use of certain of the tests described, in addition to the existing examination, would result in the selection of entrants more capable of benefiting by instruction and less liable to incur accidents.

Finally, the investigators wish to express their gratitude to the authorities in charge of the R.A.F. Training Camp at Halton and H.M. Dockyard at Portsmouth for the facilities so kindly extended during the course of the investigation. Their thanks are also due to the subjects who so willingly co-operated in the work; to Dr. Edgar Schuster for the special apparatus he designed; to Mr. M. H. Tagg for the use of his form perception tests; to Miss E. M. Newbold for statistical advice, and to the members of the Committee, on Industrial Psychology, through whose criticism considerable improvements in the method of presenting the data have been effected.

APPENDICES.

The following Appendices relate to points arising from the investigation but are not material to the main argument, and in order to keep the issue clear they have been excluded from the main body of the report

Many of the points have a theoretical and practical value beyond the issues dealt with in the report and may be regarded as bye-products of the main investigation

APPENDIX 1.

THE RELATION BETWEEN ENTRANCE AND PASSING-OUT RECORDS, AND ACCIDENTS AND SICKNESSES.

TABLE XXVII.—*Correlation Coefficients between the Passing-out Records and Accidents and Sicknesses for the R.A.F. Apprentices.*

	Groups.	School Marks.	Local Tech.	General Effic.	C.T.T.B.	Total.
Accidents ..	III	**·241**	**·192**	**·154**	**·165**	**·259**
	IV	·036	**·152**	·077	·129	·107
	V	—·041	—·011	—**·160**	—·009	—·110
	Wgtd. mean.	·107	**·120**	·040	·103	·111
Sicknesses ..	III	**·214**	**·179**	**·202**	**·119**	**·232**
	IV	**·205**	**·233**	**·263**	**·177**	**·275**
	V	—·041	·069	·089	—·053	·036
	Wgtd. mean.	**·134**	**·158**	**·181**	·079	**·183**

In two of the groups there is a fairly consistent correlation between accidents and sicknesses and the various measures of proficiency in the passing out examination. The coefficients in the case of Group V are inconsistent, and manifest no relation between proficiency and accidents and sicknesses. It has already been explained that this group changed its training centre in the middle of the training period, and moreover the accident and sickness records are not complete, and these two factors may in some way be the cause of the want of relationship between proficiency and accidents and sicknesses, though it is not very clear in what way they affect it.

There is no relation whatever between the entrance examination and the subsequent accident and sickness records of the R.A F. apprentices (Table XXVIII) From this it may be inferred that it has no prognostic value in this respect, in spite of the fact that it correlates with the final proficiency records. Such relationship as exists between proficiency and accidents and sicknesses is probably due to the lost time involved and the consequent loss in training sustained by those who have an undue number of accidents and sicknesses. The actual relationship between proficiency and accidents and sicknesses still remains somewhat indeterminate, for it has already been pointed out that the R.A.F. accident and sickness records are not reliable indicators of *real* accident and sickness rates. The want of relationship between the entrance examination and these records does not show that there is a want of relationship between it and *real* proneness to accidents and sickness, but only that it has no relation to records in

TABLE XXVIII.—*Correlation Coefficients between the Entrance Examinations and the Accident and Sickness Records for the R.A.F. Apprentices.*

	Groups.	Nomination.	Open and Service.
Accidents	III	·076	·191
	IV	041	—·197
	V	—·053	—·002
	Wgtd. mean	·032	·032
Sicknesses	III	·058	·093
	IV	·107	—·022
	V	·033	·073
	Wgtd. mean	063	·060

which error is known to be present. The relationship between the passing-out records and accidents and sickness will not be affected by this source of error if it is due to the amount of lost time caused by accidents and sickness, and is an indication that malingering, which appears to be present, has a deleterious effect upon training, as indeed would be expected.

TABLE XXIX.—*Correlation Coefficients between the Entrance Examination of the Dockyard Apprentices and Accidents and Sicknesses.*

Groups	Accidents.	Sicknesses.
VI	**·311**	·014
VII	**·236**	—·061
VIII	**·389**	**306**
IX	**·236**	—·061
Wgtd mean	**·294**	·060

It will be seen from Table XXIX that there is a definite relation between the entrance examination and accidents, showing that the method of recruiting in the dockyard does tend to select boys who are relatively free from accident proneness. Since these records represent *real* accidents the difference in the relation between the entrance examination and accidents among the R.A.F. and Dockyard apprentices is instructive and falls into line with every other difference that has been noted between the two. The entrance examination and certain of the tests both correlate with industrial proficiency and accident rate when reliable measures for either are available, and therefore presumably serve the dual purpose of indicating those who are likely to do well in the skilled trades and at the same time avoid an undue number of accidents.

APPENDIX 2.

THE RELATION BETWEEN PASSING-OUT RECORDS, AND ACCIDENTS AND SICKNESSES.

TABLE XXX.—*Correlation Coefficients between Accidents and Sicknesses and the Passing-out Records for the R.A.F. Fitters and Carpenters.*

—	Accidents		Sicknesses.	
	Fitters.	Carpenters.	Fitters.	Carpenters.
School marks	·051	157	·143	·177
Local Technical	·054	·185	·117	**·238**
General Efficiency ..	—·014	066	**·184**	·193
C.T.T.B.	·066	·163	·053	·155
Total marks . .	054	·155	**·171**	**·212**

It will be seen that the relation between accidents and sicknesses and the various measures of final proficiency is in all cases higher among the carpenters than among the fitters. There is a definite tendency for the boys who do well in the entrance examination to become fitters, the allocation to a trade depending largely upon position in the entrance examination. Most entrants prefer to become fitters, but only those who are sufficiently high in the entrance examination can make their choice effective.

TABLE XXXI.—*Comparison of the Scores in the Entrance Examinations and the Linguistic Intelligence and Cube Tests of the R.A.F. Fitters and Carpenters. (The Scores are Expressed as Percentages of Their Means and Scores under* 100 *are Better than the Average.)*

	Fitters.	Carpenters.
Nomination	94	113
Open and Service ..	96	109
Linguistic Intelligence	98	105
Cube	99	103

It is clear from Table XXXI that the fitters are on a higher intellectual level than the carpenters, and taking this in conjunction with the fact that the correlation between accidents and sickness and the passing-out records is higher among carpenters than among fitters, the natural conclusion is that the amount of time lost through accidents and sickness interferes more with the training of the less intelligent apprentices than with that of the more intelligent. The less intelligent a boy, the less he can afford to waste time during his training period. This is, of course, a truism, but it is interesting to note that the observed facts are in accordance with it.

APPENDIX 3.

THE RELATION BETWEEN ACCIDENTS IN SUCCESSIVE YEARS.

TABLE XXXII.—*The Intercorrelation Coefficients between Different Years' Accidents.*

—	Groups	1st year.	2nd year.	3rd year.	4th year.
1st year . .	III	—	**·382**	**·338**	—
	IV	—	**·390**	**·223**	—
	VI	—	·053	**·841**	·028
	VII	—	**327**	**·327**	—
	VIII	—	**·568**	—	—
	Wtd. mean	—	**·377**	**·336**	·028
2nd year . .	III	**·382**	—	**·443**	—
	IV	**·390**	—	**360**	—
	VI	·053	—	**·269**	204
	VII	**·327**	—	**·246**	—
	VIII	**·568**	—	—	—
	Wtd mean	**·377**	—	**·389**	·204
3rd year . .	III	**·338**	**·443**	—	—
	IV	**·223**	**·360**	—	—
	VI	**·841**	**·269**	—	**·366**
	VII	**·327**	**·246**	—	—
	VIII	—	—	—	—
	Wtd mean	**·336**	**·389**	—	**·366**
4th year .	III	—	—	—	—
	IV	—	—	—	—
	VI	·028	204	**·366**	—
	VII	—	—	—	—
	VIII	—	—	—	—
	Wtd. mean	·028	·204	**·366**	—

Weighted mean coefficient between all periods = **·358.**

Note.—The coefficients for Groups VI, VII and VIII were obtained by the fourfold method of correlation

Newbold* found correlation coefficients between accidents sustained in different periods by the same workers varying between ·20 and ·60, so that the mean intercorrelation coefficient between the four years' exposure is in agreement with her findings.

It is interesting to note that the correlation between *successive* years' accidents is in all cases slightly higher than that between *non-successive* years. The difference is only in the second place of decimals, but it may show that there is some temporary factor affecting accident rate, though its operation is small.

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* Industrial Fatigue Research Board Report No. 34.

APPENDIX 4.

RELATION BETWEEN TESTS AND ACCIDENTS FOR DIFFERENT PERIODS OF EXPOSURE.

TABLE XXXIII.—*Fourfold Correlation Coefficients (Q5s) between Summed Aesthetokinetic Tests and Accidents for the Four Groups of Dockyard Apprentices for Varying Periods of Exposure.*

Groups.	Q5.	
VI ..	**·444**	(4 years' accidents)
VII ..	**·439**	(3 years' accidents)
VIII ..	**·217**	(2 years' accidents)
IX ..	·099	(1 year's accidents)

The data presented in Table XXXIII is for small groups, and the fourfold method of correlation has been used so that too great reliance should not be placed upon it, but it is interesting to note that the magnitude of the correlation coefficients increases with the length of exposure—the longer the exposure the greater the correlation. In spite of the correlations found by Greenwood and Woods* and Newbold† between the number of accidents sustained by workers in different periods, and those presented in Table XXXII of this report, it is clear that the accident rate for any period less than the whole working life must be an imperfect measure of an individual's accident proneness.

Any tests which purport to measure real accident proneness freed from such temporary influences as age and inexperience should correlate with accident rate in direct proportion to the length of the period of exposure from which the rate was obtained The longer the period of exposure the nearer does accident rate tend to be a true measure of accident proneness. Since it has been shown that the correlation between the aesthetokinetic tests and accident rate does vary directly with the length of exposure as far as the present data goes, this correlation will be seen to be in agreement with the above axiom. Presumably, therefore, the aesthetokinetic tests measure a factor in accident proneness whose effect can never be fully determined until the accident rate of the whole working life is known.

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* Industrial Fatigue Research Board Report No. 4.
† Industrial Fatigue Research Board Report No. 34.

APPENDIX 5.

METHODS OF CORRELATION EMPLOYED.

Three methods of calculating the correlation between two variables have been used in this report

1. *The Product-moment Method.*—This is the most satisfactory method. Suppose we are dealing with a group of N subjects and these subjects have two attributes measured by the viarables A and B. Then if the values of the variables are a_1, a_2, a_3, ... a_n, and b_1, b_2, b_3, ...b_n, respectively for the N subjects, the coefficient of correlation, r, is given by the following formula :—

$$n = \frac{m_A \; m_B - \frac{\Sigma\,(AB)}{N}}{\sigma_A \quad \sigma_B},$$

where m_A, m_B, = means of A and B resp.

Σ(AB) = sum of products (a_1 b_1), ($a_2 b_2$)........(a_n b_n)

N = number of subjects.

σ_A σ_B = standard deviations of A and B resp

2. *The Ranking Method* —In the ranking method the two variables are ranked in order of magnitude, and the numerical difference between the two ranks obtained by each subject written down irrespective of sign. If this difference is called d, then the coefficient of correlation, p, is given by the formula

$$p = 1 - \frac{6\Sigma\;(d^2)}{N\;(N^2\text{-}1)},$$

where N = the number of subjects.

3. *The Four-fold Method*—This method is used only when the two variables are capable only of a dichotomous division. A table is constructed showing the numbers of subjects who are

i. better than the mean of both A and B,
ii worse than the mean of both A and B,
iii. better than the mean of A and worse than the mean of B,
iv. better than the mean of B and worse than the mean of A.

This gives a "fourfold" table as under :—

	Better in A	Worse in A	
Better in B	a	b	N
Worse in B	c	d	

In this table a, b, c, and d, represent the number of subjects falling into the four groups, and N is the sum of a, b, c, and d, *i.e.* the total number of subjects. The coefficient, Q5, is then given by the following formula :—

$$Q5 = \sin\left(\frac{\pi}{2} \cdot \frac{1}{\sqrt{1+k^2}}\right),$$

$$\text{where } k^2 = \frac{4.\,a.\,b.\,c.\,d.\,N^2}{(ad - bc)^2\,(a + d)\,(b + c).}$$

In practice it is not necessary to calculate the trigonometrical function since tables shewing the values of Q5 corresponding to values of log k^2 are available.

APPENDIX 6.

THE RELATION BETWEEN DIFFERENT PASSING-OUT RECORDS *

TABLE XXXV.—*The Intercorrelation Coefficients between the Various Passing-out Records of the R.A.F. Apprentices.*

	Group.	School Marks.	Local Tech	Gener. Effic.	C.T.T.B.	Total Marks.
School marks . .	III	—	**·540**	**·398**	**·503**	**·816**
	IV	—	**·494**	**·299**	**·391**	**·766**
	V	—	**·591**	**472**	**·482**	**·821**
Local Tech. . .	III	**·540**	—	**·280**	**463**	**·605**
	IV	**·494**	—	**448**	**·706**	**·759**
	V	**·591**	—	**·542**	**·498**	**·692**
General Efficiency.	III	**·398**	**·280**	—	**·317**	**·635**
	IV	**299**	**·448**	—	**·381**	**·639**
	V	**·472**	**·542**	—	**·379**	**·744**
C.T.T.B. . .	III	**·503**	**463**	**·317**	—	**·816**
	IV	**·391**	**706**	**·381**	—	**·767**
	V	**·482**	**·498**	**·379**	—	**·774**
Total Marks . .	III	**·816**	**·605**	**·635**	**·816**	—
	IV	**·766**	**·759**	**·639**	**·767**	—
	V	**·821**	**·692**	**·744**	**·774**	—

The high intercorrelation coefficients in this table indicate that general efficiency and smartness and practical and theoretical understanding are all closely related

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* See page 47

APPENDIX 7.

COMPARISON BETWEEN THE PASSING-OUT RECORDS OF (*a*) NOMINATION AND (*b*) OPEN AND SERVICE R.A.F. CANDIDATES *

TABLE XXXVI.—*The Average Score in the Passing-out Records for the Nomination and the Open and Service R.A.F. Candidates Separately.* (*Scores are Expressed as Percentages of the Means of the whole Groups.*)

——	Groups	Nomination	Open and Service.
School Marks .. .	III	102	95
	IV	102	95
	V	101	98
	Wgtd mean	102	96
Local Technical ..	III	101	98
	IV	100	100
	V	101	99
	Wgtd mean	101	99
General Efficiency ..	III	99	102
	IV	99	101
	V	99	101
	Wgtd. mean	99	101
C.T.T B. . ..	III	101	97
	IV	101	97
	V	101	99
	Wgtd. mean	101	98
Total Marks .. .	III	101	98
	IV	101	98
	V	100	99
	Wgtd. mean	101	98

It will be seen that the passing-out scores of the apprentices entering by either examination are practically equal, so that it cannot be claimed that one method has any advantage over the other.

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* See page 51.

APPENDIX 8.

THE RELATION BETWEEN ACCIDENTS AND SICKNESSES.

TABLE XXXVII.—*The Correlation between Accidents and Sicknesses.*

Group.	
III	·504
IV	·571
V	·294
VI	272
VII	−·013
VIII	·207
IX	·500
Wgtd. mean	·409

The correlation which is shown to exist between accidents and sicknesses is in accordance with those which have previously been found. Whether the correlation is due to a real relationship between ill-health and a liability to sustain accidents, or whether it is due to a tendency to report both accidents and sicknesses cannot be determined by the present data It may, however, be assumed that any selective tests which reduce accident rate will also tend to reduce sickness rate and so avoid a certain amount of lost time.

APPENDIX 9.

RELATION BETWEEN THE VARIOUS SUBJECTS IN THE ENTRANCE EXAMINATION AND FINAL PASSING-OUT RESULTS.

The subjects in the entrance examination for the R A F apprentices are mathematics, science, English composition, and a general paper It is possible to obtain a maximum of 200 marks for mathematics, and 100 for each of the other subjects It is clear from the correlation coefficients in Table XXXVIII that this method of weighting the subjects in the examination is not calculated to give the highest correlation with the passing-out records Whether passing-out total or practical total be taken as the best criterion for assessing the value of the entrance examination, science should have a higher weight than it does at present According to its correlation with the final results it should have a weight at least equal to that of mathematics, and if practical total be taken as the best criterion for judging the value of the entrance examination (and there are many reasons to recommend this) then the weight assigned to science should be greater than that assigned to mathematics, instead of being only half, as it is at present A higher final weighted correlation between the entrance examination combined with the psychological tests and the final records could have been obtained by weighting the subjects of the examination according to the coefficients given in Table XXXVIII, but it was decided not to do this until the examining authorities had had an opportunity of reading the report

TABLE XXXVIII.—*Correlation Coefficients between the Separate Subjects in the Open and Service Entrance Examination for the R.A.F. Apprentices and* (1) *Passing-out Total and* (2) *Practical Total.*

(1) With passing-out total —

Group.	Mathematics	Science.	General.	English.
III . ..	333	·451	·222	202
IV ..	·235	·295	·210	·165
V . ..	·415	·389	·336	·271
Wgtd mean ..	·341	·393	·261	·219

(2) With practical total —

Group	Mathematics.	Science.	General	English.
III .. .	155	·326	·104	·119
IV	·034	·201	·083	·047
V	·289	·255	·204	·183
Wgtd. mean ..	·177	·272	·136	·126

APPENDIX 10.

THE EFFECT OF AGE ON PERFORMANCE IN THE TESTS.

Figure 5 shows the age curves for the tests used in the final weighted combination. There is a general tendency for age to improve performance, and this, as might be expected, is more marked in the case of the dynamometer than in any other test The numbers tested are not sufficient to establish age norms of a reliable nature, so that no correction was made for age in the tests scores, but this will probably have to be done at a later period when more subjects have been tested. The only reason for publishing these curves at present is to indicate the probable nature of age norms in each of the tests.

Note—All scores are expressed as percentages of their means and scores under 100 are better than the average Bracketted figures indicate the numbers in each age.

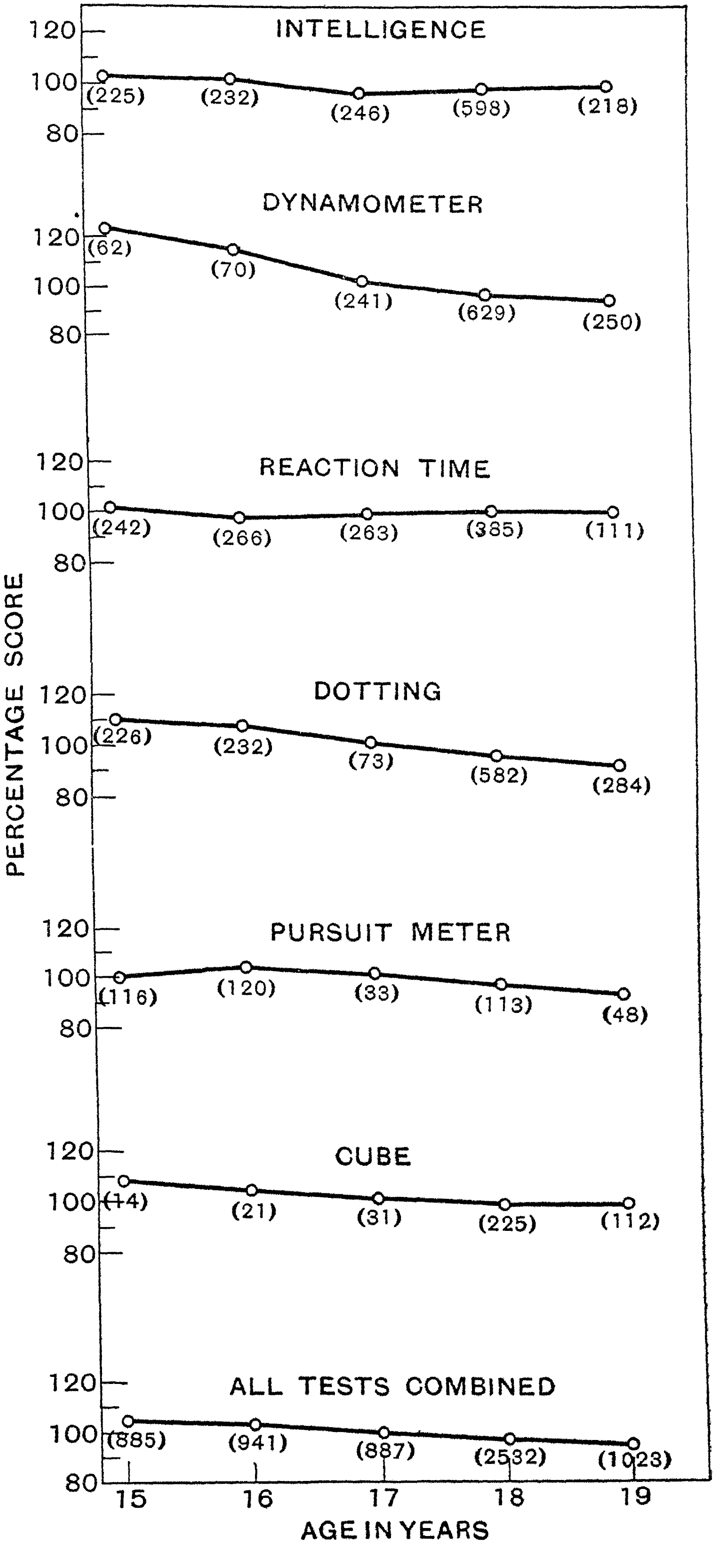
INTELLIGENCE
(225)
(232)
(246)
(598)
(218)
DYNAMOMETER
(62)
(70)
(241)
(629)
(250)
REACTION TIME
(242)
(266)
(263)
(385)
(111)
DOTTING
(226)
(232)
(73)
(582)
(284)
PURSUIT METER
(116)
(120)
(33)
(113)
(48)
CUBE
(14)
(21)
(31)
(225)
(112)
ALL TESTS COMBINED
(885)
(941)
(887)
(2532)
(1023)
120
100
80
PERCENTAGE SCORE
15
16
17
18
19
AGE IN YEARS

FIGURE 5

APPENDIX 11.

DESCRIPTION OF NEW APPARATUS.

1 *The co-ordination test.*

This apparatus was designed to measure a subject's ability to make rapid and accurate co-ordinated movements with both hands simultaneously. The actual task he has to perform is to control a movable green disc, by means of turning two handles at right angles to one another, so that it is maintained vertically above a second, white, disc which is controlled mechanically and moves in an irregular space and velocity pattern.

The mechanism by which the white disc is controlled is as follows A horizontal circular metal plate, A (Fig. 6), mounted on a vertical axis and rotated by a gramophone motor, has a small curved slit, B, pierced through it. Through this slit projects a rider, C The rider is fixed to the plate in such a way that it can move from end to end of the slit, and it is kept pressed to the edge of a horizontal plate cam of irregular outline, D, by means of a spring, E The rider is fitted with a wheel bearing so that it moves smoothly along the edge of the cam. This cam is fixed and does not move at all, so that when the plate A rotates the rider C describes an irregular path, the resultant of excursions of varying length towards and away from the centre of the plate imposed on a circular orbit The velocity of these transverse excursions also varies, depending on the angle of the irregularities in the cam, so that the rider has also an irregular velocity pattern. The white disc which the subject is required to follow is fitted to a small brass cylinder and screwed on to the rider C

The part of the apparatus under the subject's control consists of a graduated drum, F, on a carriage bearing a short metal arm at the end of which the green disc, G, is fixed. The carriage slides towards or away from the subject along a guide bar, H, and the bar H itself, together with the carriage and drum, slides along two guide bars, J and J^1, at right angles to H, and hence to the subject's left or right. This sliding is controlled by two long screw spindles situated beneath bars H and J^1 and ending in handles K and L. When the handle K is turned the carriage bearing the drum is moved along the bar H in a direction depending on the way K is turned, clockwise turning moving it towards the subject and anti-clockwise away from him. Similarly, when L is turned the bar H with the drum and carriage moves along the bars J to the subject's left or right according as the turning is clockwise or anti-clockwise. Hence, when both handles are being turned at once the motion of the green disc is the resultant of two motions at right angles to one another, so that G can be moved over any part of the plate A by judicious turning of K and L Also the velocity of G is the resultant of two velocities at right angles, and can be controlled at will. The two screw spindles are of different pitches, so that L has to be turned oftener than K to move G the same distance

The subject's ability to keep the green disc over the white one is measured by means of the graduated drum. This drum is in two parts, both rotatable about a vertical axis and connected together by a friction ratchet of the ball and inclined plane type. When the lower part of the drum is rotated in an anti-clockwise direction the upper part is carried with it, but when the rotation is clockwise the upper part is prevented from turning by a second friction ratchet working on a fixed axis The lower part is fitted with a watch spring so that anti-clockwise rotation is always made against the action of the spring. Round a groove at the bottom of this lower part of the drum passes a cord, M, of which one end is secured to the drum and the other, after passing through an eyehole in the green disc, is secured to the white disc. Hence, when the green and white discs are moved apart the cord is pulled out and rotates the drum in an anti-clockwise direction, causing the graduations on the upper part of the drum to move past a pointer, N. When the discs come together again the spring in the drum automatically rotates the lower part in a clockwise direction, thus taking up the slack in the cord but not moving the upper part of the drum In this way the rotation of the upper part of the drum sums the various deviations of the green disc from the white one, and the reading on the graduations thus gives a quantitative measure of the subject's ability to keep the two discs together. The drum is set to zero for each subject by rotating the upper part by hand in an anti-clockwise direction.

There is a simple stopping device fixed to the gramophone motor so that when the machine is started the plate A makes one revolution and then stops automatically. In this way each subject has precisely the same task to perform and the various scores of the subjects are directly comparable One revolution of the plate takes 100 seconds

(2) *The steadiness test.*

This test makes use of the apparatus described above with the following alterations The white disc is unscrewed from the rider C and the handles K and L turned to their full extent so that the plate A is left clear. A small stainless steel cup, O (Fig. 7), is then screwed to the rider When the machine is started the cup O describes the same space and velocity pattern as did the white disc in the co-ordination test •The subject is provided with a stylus, P, ending in a stainless steel ball, and he is required to hold this ball inside the cup as it moves round and to prevent it from touching the sides or bottom of the cup as far as he is able He has to take the stylus in his master hand and hold his arm quite freely. Whenever the ball and cup come into contact an electric circuit containing a buzzer, an electromagnet, and a 4-volt accumulator is made. The subject is thus warned by the buzzer when he allows the ball to touch the cup.

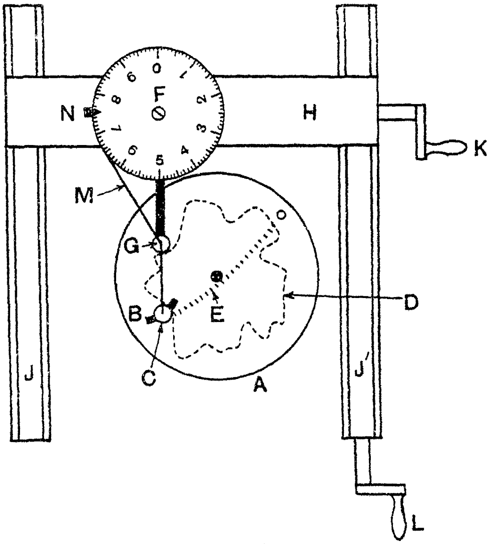

FIGURE 6

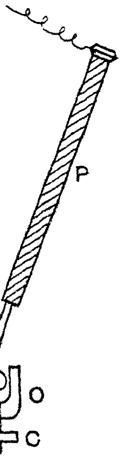

FIGURE 7.

The score is recorded on a graduated disc situated under the plate A. This disc is rotated by friction, being attracted into contact with another rotating disc whenever the cup and ball are in contact and the electromagnet activated by the electric circuit thus made. It is possible to read off from this graduated disc how many seconds out of the 100 second revolution of the machine the cup and ball are in contact. The disc is set to zero by hand for each subject, and the score read off in each case is a summation of all the periods of contact between the ball and the cup.

3. *The interrupted pursuit meter test.*

The pursuit meter apparatus already described in Report No. 38, pp. 43, 44, was used as a basis for this test. The subject was required to perform this test in the manner there described, moving the pointer with his right hand. Whilst he was performing this task certain visual and auditory stimuli were given him, to which he had to respond with his left hand and with his feet.

The visual stimuli consisted of a red and a white disc They were arranged at the back of the pursuit meter apparatus, A (Fig 8), so that as each of them was presented the subject could see it without removing his eyes from the moving pointer Under the subject's left hand were two reaction keys, B , these were of the Morse type and each bore a coloured index to show which was the red and which the white response key.

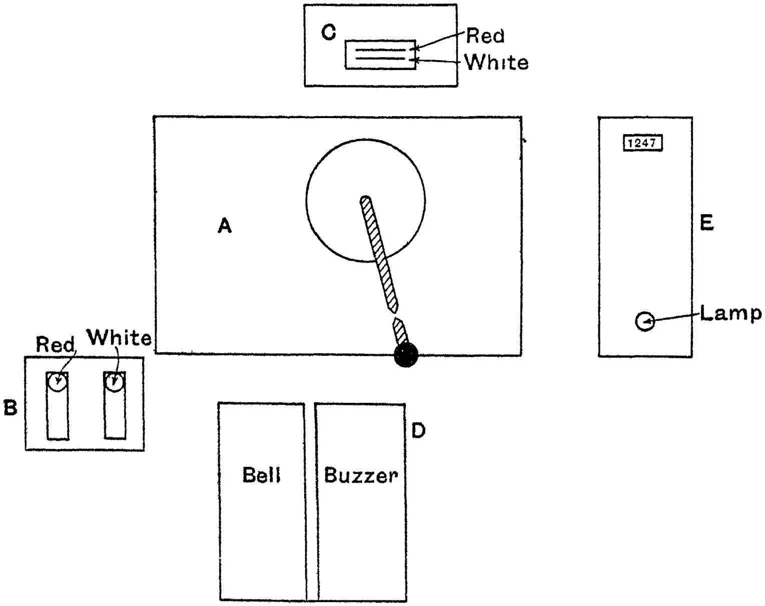

FIGURE 8.

The auditory stimuli were a bell and a buzzer and were situated in the same box, C, as the visual stimuli. The subject sat with his feet resting on two pedals labelled Bell and Buzzer and as each of these stimuli was presented he was required to press down the corresponding pedal. (*See* D, Fig. 8.)

Twenty of these stimuli were given at irregular intervals during the 60 seconds which the subject had to spend following the pursuit meter pointer. In order to score a correct response to a stimulus the response had to be made within a short interval (approximately two seconds) after the stimulus had been given. The number of correct responses was recorded electrically on a Veeder counter in the box E. The stimuli were presented and the responses recorded electrically. The appearance of each stimulus was regulated by a rotating drum fixed inside the pursuit meter box and actuated by the same motor. Hence, the number and time of presentation of the stimuli were identical for all subjects.

The electrical connections of this apparatus are rather complicated and need not be described in detail here. They performed the following functions :—

(1) They caused the stimuli to appear.

(2) They recorded correct responses.

(3) They made it impossible for a subject to score a response by pressing two response keys simultaneously.

(4) They caused a light to shine in the box E if the subject pressed any response key when no stimulus was being given. This apprised the experimenter of the fact that the subject had a key depressed and enabled him to make the subject remedy this. Otherwise the subject might score a correct response by chance (if the corresponding stimulus happened to appear whilst he had the response key depressed), or it would prevent his making a correct response to a different stimulus.

A single score was obtained for the whole of this test by adding together the scores obtained for the pursuit meter and for the reaction responses, having first expressed each score as a percentage of the mean score for the whole group tested.

APPENDIX 12.

RELIABILITY OF CERTAIN OF THE TESTS

Only a rough measure of the reliability of the tests was obtainable since none of them was given to any group more than once. It was possible in certain of the tests, however, to correlate one half of the score with the other half. This was done for all the tests in which it was possible and the results are as follows —

Test	*Number of subjects.*	*r between the two halves of the test*
Reaction time	161	**·693**
Pursuit meter ..	174	**·644**
Rectangles .	347	·076
Stereoscope	413	**·550**

Correlations were not obtained from every group for each of these tests, but they were worked out for groups with sufficient numbers in them to render the coefficients reliable

The coefficients in the case of reaction time, pursuit meter and stereoscope are high enough to justify the assumption that these tests are relatively reliable The insignificant coefficient obtained from the rectangles test indicates that this test is an unreliable one, and it has already been pointed out in the text of the report that it appeared to involve chance factors in a high degree. Since no conclusions have been drawn with regard to the rectangles test the fact that it appears to be unreliable makes no difference to our general results.

Another rough method of estimating the reliability of the tests is to note their consistency in the various groups tested, and a statistical measure of this is given in Appendix 13.

APPENDIX 13

CONSISTENCY OF THE CORRELATIONS

Stress has been laid in the report on the fact that the values of the correlations between tests obtained in the different groups were fairly consistent An attempt has been made to measure this consistency by comparing the observed distribution of the coefficients about their mean with a normal curve The distribution of sampling errors of coefficients of correlation does not, of course, tend to a normal curve unless the number of observations is very large, and still less so if the coefficients are themselves large In this case the correlations are mostly of about the order of ·3 and the numbers of observations range from 57 to 524, so that a normal curve may perhaps provide a very rough test of consistency.

Only four of the tests had been given a sufficient number of times to provide a reasonable sized distribution of r's. In these four there is no glaring discrepancy between the observed cluster and that of the normal curve, the greatest deviation being that of number setting (*see* Table). Hence, the observed mean of the coefficients may be taken as a fairly reliable estimate of the correlation among the subjects tested

TABLE XXXIX.—*Deviations of the r's from the Estimated r's in Terms of Their Standard Deviations.*

Deviation s d. between.	Dotting		Reaction		Number setting		Linguistic Intelligence.	
	Observed	Normal curve	Observed	Normal curve	Observed	Normal curve	Observed.	Normal curve.
0—1 ..	54	47·8	36	31·4	42	41·0	41	41·0
1—2 ..	12	19·0	6	12·5	15	16·3	16	16·3
2—3 ..	4	3·2	4	2·1	3	2·7	3	2·7
3—4 ..	—		—		—		—	
Over 4 ..	—		—		—		—	

All the intercorrelations of Dotting with the other tests are grouped together in the column headed " Dotting," and similarly for the other tests.

APPENDIX 14.

THE PARTIAL CORRELATION COEFFICIENTS OF THE SIMPLE AESTHETOKINETIC TESTS WITH INDUSTRIAL PROFICIENCY AND ACCIDENT RATE.

Partial correlation coefficients were calculated between the simple aesthetokinetic tests and the objective criteria of industrial proficiency and accident rate , and the mean correlation coefficients between each aesthetokinetic test and these objective criteria, keeping the other two aesthetokinetic tests constant are given below Practical Total (*see* page 53) was chosen as the criterion of industrial proficiency.

Correlation coefficient between *practical total* and :—

reaction, keeping dotting and pursuit meter constant = ·075
dotting, keeping reaction and pursuit meter constant = ·068
pursuit meter, keeping reaction and dotting constant = ·037

Correlation coefficient between *accident rate* and .—

reaction, keeping dotting and pursuit meter constant = ·066
dotting, keeping reaction and pursuit meter constant = ·114
pursuit meter, keeping reaction and dotting constant = ·024

The smallness of the partial correlation coefficients indicates that the factor that the simple aesthetokinetic tests have in common is the same factor that determines the correlation between the aesthetokinetic tests and these objective criteria. In other words, if aesthetokinesis is the psychological function common to the aesthetokinetic tests, industrial proficiency and accident rate must also comprise aesthetokinesis amongst the complex of psychological functions they involve. If the suggestion put forward on page 34, that tests are dependent on a number of dominant factors, is true, then a group of tests could intercorrelate among themselves on account of some common dominant factor and correlate with an objective criterion such as industrial proficiency on account of factors specific to each test. This apparently is not the case with the simple aesthetokinetic tests. The partial correlations are so small as to indicate that the correlation between the tests and these criteria is almost wholly determined by the factor that the tests have in common

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Lupton, H. (1923): An Analysis of the Effects of Speed on the Mechanical Efficiency of Human Muscular Movement.—*J. Physiol.*, **57,** 6.

Muscio, B. (1920): Fluctuations in Mental Efficiency.—*Brit. J. Psych.*, **10,** 4.

Muscio, B. (1921): Is a Fatigue Test Possible?—*Brit. J. Psych*, **12,** 1

Muscio, B. (1921): Feeling Tone in Industry.—*Brit J Psych*, **12,** 2.

Muscio, B. (1922): Motor Capacity with Special Reference to Vocational Guidance.—*Brit. J. Psych.*, **13,** 2.

Muscio, B., and Sowton, S. M. (1923): Vocational Tests and Typewriting —*Brit. J. Psych.*, **13,** 4.

Newbold, E. M. (1923): Note on Dr. Burnside's Paper on Errors of Observation.—*Biometrika*, **15,** 3 & 4.

Pear, T. H. (1927): Repetitive Work.—*Dictionary of Industrial Administration.*

Pear, T. H. (1927): Work, Temperament and Fatigue.—*Rep. Internal Ass. for Study of Relations and Conditions in Industry.* (Baveno), 1927.

Pear, T. H., (1927): Recent Studies of Skilled Performance with reference to Transfer of Training.—*Nature*, 18th Jan.

Pembrey, M. S., and Others (1922): Tests for Physical Fitness.—Part I.—*Guy's Hospital Reports*, Oct., 1921. Part II.—*Ibid*, Oct., 1922

Rusher, E. A. (1922): The Statistics of Industrial Morbidity in Great Britain.—*J. Roy. Stat. Soc.*, **85,** 1.

Sargent, R M (1926): The Relation between Oxygen Requirement and Speed in Running.—*Proc. Roy. Soc. B.*, Vol. **100,** 1926.

Smith, May (1923): Practical Problems of Industrial Life.—*Ind. Welfare*, **5,** 58.

Smith, May (1923): The Laundry Trade.—*Laundry Record*, **33,** 388.

Smith, May (1926): Industrial Psychology.—*Article in Encyclopædia Britannica (XIIth Edition).*

Sturt, M. (1922): A Comparison of Speed with Accuracy in the Learning Process.—*Brit. J. Psych.*, **12,** 3.

Vernon, H. M. (1921): The Influence of Atmospheric Conditions on Industrial Efficiency.—*J. State Med.*, **29,** 353.

Vernon, H. M. (1921): The Influence of Fatigue on Health and Longevity. —*J. Ind. Hyg.*, **3,** 3.

Vernon, H. M. (1922): Recent Investigation on Atmospheric Conditions in Industry.—*J. Ind. Hyg.*, **4,** 8.

Vernon, H. M. (1923): A Note on the Causes of Output Limitation.—*J. Nat. Inst. Ind. Psych.*, **1,** 5.

Vernon, H. M. (1923): Atmospheric Conditions in Potters' Shops and the Efficiency of Various Types of Drying Stoves.—*Trans. Ceramic Soc.*, 22, p. 70.

Vernon, H. M. (1923): The Causation of Industrial Accidents.—*J. Ind. Hyg.*, **5**, 1.

Vernon, H. M., and Bedford, T. (1924): The Influence of Short Time on Speed of Production.—*J. Nat. Inst. Ind. Psych.*, **2**, 155.

Vernon, H. M. (1925): Can Laboratory Experiments on Output throw Light on Problems of Industrial Fatigue ?—*Brit J. Psych.*, **15**, 4

Vernon, H. M. (1925): The Kata-Thermometer as an Indicator of Radiant Heat—*J. Nat Inst Ind. Psych.*, **2**, 198.

Vernon, H. M. (1925): The Work of the Tin-Plate Doubler.—*J. Nat. Inst. Ind. Psych.*, **2**, 373.

Vernon, H. M. (1926): Is Effective Temperature or Cooling Power the Better Index of Comfort?—*J. Ind. Hyg.*, **8**, 392.

Vernon, H. M. (1927): The Elimination of Fatigue caused by Extremes of Temperature, Humidity and Dust—*Rep. Internat. Ass. for Study of Human Relations and Conditions in Industry.* (Baveno), 1927.

Vernon, H. M. (1927): Ventilation in relation to Health.—*J. State Med.*, **34**, 683.

Vernon, H. M. (1927): The Wet Kata-thermometer as an Index of the Suitability of Atmospheric Conditions for Heavy Work.—*J. Indust Hyg.*, **9**, 287.

Vernon, H. M., and others (1926): Methods of Investigating Ventilation and its Effects—*Med. Res. Council Spec Rep Series No* 100.

Vernon, H M., and Bedford, T. (1927): The Ventilation and Heating of Factories.—*J. Indust. Hyg.*, **9**. 51.

Vernon, H. M, and Vernon, M D. (1927): The Physical and Physiological Effects of Radiant Heating by the Panel System.—*Proc. Physiol. Soc., J. Physiol.*, **64**, 1.

Vernon M D (1926): On Certain Effects of Long Spells of Repetitive Work—*Brit. J Psych.*, **16**, 3.

Warner, E C., and Hambly, W. D. (1925): An Investigation into the Physiological Basis of the U-tube Manometer Test.—*Guy's Hosp. Rep.*, July, 1925.

Weston, H. C (1927): The Relation between Illumination and Efficiency in Fine Processes, with special reference to the Lighting of Printing Works.—*Illum. Engineer*, **20**, 221.

Weston, H. C. (1927): Light and Vision in Industry.—*Rep. Internat. Ass. for Study of Human Relations and Conditions in Industry* (Baveno), 1927.

Wilson, D. R (1921): Some Effects of Environment on Efficiency and Safety.—*J. Roy. San. Inst.*, **42**, 3.

Wilson, D. R. (1921): The Work of the Industrial Fatigue Research Board, and its Applications to Industry.—*J. Roy. Soc. Arts*, **70**, 3660.

Wilson, D. R. (1923): On Some Recent Contributions to the Study of Industrial Fatigue.—*J. Roy. Stat. Soc.*, **86**, 4.

Wilson, D. R. (1923): International Co-operation in the Study of Industrial Psychology and Physiology.—*International Labour Office, Studies and Reports, Sec. F., No.* 9.

Wilson, D. R. (1924): Some Observations on Industrial Lighting.—*J. Ind. Hyg.*, **5**, 10.

Wilson, D. R. (1924): Man in Relation to Production.—*First World-Power Conference*, **412**.

Wyatt, S. (1925): The Effect of Atmospheric Conditions on Health and Efficiency (with special reference to the Cotton Industry).—*J. Ind. Hyg.*, **7**, 7.

Wyatt, S. (1927): An Experimental Study of a Repetitive Process.—*Brit. J. Psych*, **17**, 3.

Wyatt, S. (1927): Machine Speeds and Output.—*J. Nat. Inst. Indust. Psych.*, **3**, 8.

Wyatt, S., and Weston, H. C. (1920): A Fatigue Test under Industrial Conditions.—*Brit. J. Psych.*, **10**, 4.

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INDUSTRIAL
FATIGUE RESEARCH BOARD.

The Effects of Monotony in Work.

A Preliminary Inquiry

by

S. Wyatt, M.Sc., M.Ed., and J. A. Fraser, M.A.,
assisted by F. G. L. Stock.

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PREFACE.

The wholesale replacement of manual by mechanical methods of production that has occurred over a long period in the past and is still vigorously continuing, has tended to focus attention on the mental rather than the bodily effects of work, and as an influence in industrial life boredom is now rightly regarded as no less important than fatigue.

Previous investigations conducted for the Board have suggested how the effects of monotonous work can be alleviated, as for instance by the introduction of short rest-pauses into the usual spells of work and by periodic changes in the nature of the activity. These, however, have rested on a purely empirical basis, and little up to the present has been done to study the prevalence and nature of boredom outside the controlled conditions of the laboratory.

The present report is a first step in that direction. It is based mainly on the close observation of operatives engaged in different occupations of a repetitive kind, and from the output curves so obtained, combined with the subjective impressions of the operatives concerned, an attempt is made to draw certain inferences as to the incidence and symptoms of boredom.

Though the study, as the authors themselves point out, is merely preliminary, certain conclusions emerge which the Board think may eventually be found to be of practical importance. It is clear, for instance, that individuals differ widely in their susceptibility to boredom, from the entirely immune to those who find monotonous work continuously distasteful, though adaptation appears to play an important part in determining the ultimate attitude of the worker towards his conditions of work. Again, some evidence exists that between work involving skill and completely automatic work there is a certain degree of mechanisation when attention is neither concentrated nor entirely free, that is most favourable to the development of boredom, which might accordingly be relieved to some extent by still further mechanisation. Lastly, the conditions under which the work is done, such as remuneration on a piece rate basis, aggregation in groups, talking, and other similar factors probably have an appreciable influence in eliminating or reducing the unpleasant effects of monotonous work.

June, 1929.

THE EFFECTS OF MONOTONY IN WORK.

A Preliminary Inquiry

BY

S. WYATT, M Sc., M.Ed , and J. A. FRASER, M.A.,
assisted by F. G. L. STOCK.

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I. Nature of Boredom.

A consideration of the nature of boredom may be conveniently approached by contrasting it with interest, since one is due to the absence of certain elements which are present in the other. Activities are usually interesting when they appeal to one or more of the fundamental instinctive tendencies, or to some acquired disposition based upon these tendencies. The curiosity displayed by a youth in the working of a machine and the interest of the speculator in the stock exchange, are examples To be interested means that we attend spontaneously to the object or situation which appeals to our inclination or desires, and we continue to do so until either satisfaction is achieved or the tendency is neutralised by the effects of fatigue. A characteristic feature of interesting activities is that they are performed with a minimum of effort. The curve of work obtained under such conditions usually exhibits a high level of performance and only begins to decline as the effects of fatigue increase.

Conversely, activities that fail to harmonise with the desires of the individual or make no appeal to the instinctive tendencies are usually uninteresting and unsatisfying. The natural inclination of all individuals is to discontinue activities which are unpleasant, so that if this is impossible they are only continued at the expense of increased volitional effort. In such cases, effort is not only required to perform the necessary movements ; it must also be used to repress the intruding ideas and desires. Thus, work under such conditions may very quickly become distasteful and unsatisfying, and the resulting experience is known as boredom.

It is obvious that boredom, at least in its early stages, is something quite distinct from fatigue. An audience may be intensely bored by a lecture, but as a rule it is far from being fatigued. Continued exposure to such conditions may, of course, lead eventually to a certain amount of weariness, but a sudden change in the proceedings will speedily reawaken interest, and restore the enthusiasm which had gradually faded away. Boredom, therefore, is a psychical state which may exist quite apart from fatigue, and must be separately considered in any industrial inquiry dealing with factors which impair production.

The nature of boredom has been the subject of several theoretical and experimental contributions to psychological literature, and a brief reference to the more important publications will indicate the lines along which inquiries have proceeded.

One of the earlier writers, Rümelin,[1] stated that the continuance of work involved the enforced expenditure of effort, together with the repression of distracting stimuli arising from the activity of unfatigued mechanisms and natural impulses. As a result, dissatisfaction was said to be caused not only by the thwarting of natural inclinations, but also by the repeated inhibition of contrary desires and tendencies.

---

[1] "Reden und Aufsätze." Neue Folge. Freiburg. 1881.

von Schubert-Soldern[1] approached the question by comparing the nature of the movements involved in work and in play. He pointed out that the manipulative activities of the industrial operative are restricted and controlled by the conditions of work and lack the freedom and variety of those expressed in play. In play movements are said to be spontaneous and satisfying; in work the movements are not pleasant in themselves, but require effort for their continuance.

A somewhat different view has been taken by other writers, who have attempted to determine the nature of the reaction to repeated stimuli of a uniform and varied kind. Ranschburg,[2] for instance, found that the apprehension and reproduction of the separate components of a uniformly repeated series was more difficult than in a varied series. Münsterberg[3] also, as the result of a number of laboratory experiments, put forward the view that individuals differ in their reception of uniformly repeated stimuli. In some subjects each repetition was facilitated by the one which preceded it, and performance was said to be comparatively free from effort and accompanied by satisfaction. In others, the reception of each impression inhibited the reaction to the next in the series, and the subjects were obliged to attend to each in turn. The effort involved created a feeling of displeasure, and the conditions were said to be monotonous. Thus boredom appears to be associated with difficulty in the reception of uniformly repeated stimuli, and is most marked in those individuals who are compelled to attend to each successive impression.

Winkler,[4] continuing this line of investigation, came to the conclusion that individuals who suffer from boredom are those who find it necessary to give some, but not the whole, of their attention to work He found that several of his subjects maintained a fairly uniform rate of working, and these, with one exception, stated that the work was pleasant. Either they were able to work automatically, in which case their thoughts were, as a rule, wholly detached from the process, or they were wholly concentrated on the task and found satisfaction in the recurring homogeneous impressions. The remainder showed an initial improvement in their rate of working, followed by great variations, during which they displayed many signs of boredom such as restlessness, yawning, looking at the clock and the like These symptoms, which occurred after work had been in progress for about an hour, were attributed by Winkler to a psychological "stirring-up" originating from a revulsion of feeling caused by the aimless and tedious nature of the work.

---

[1] *Zeits f. d. ges. Staatswissenschaften.* 1896.

[2] *Journ. f. Psychol. u. Neurol.* 5. 1905.

[3] "Psychology and Industrial Efficiency." London. 1913.

[4] "Die Monotonie der Arbeit." *Zeits. f. ang. Psychol.* Vol. 20, 1922.

More recently Myers[1] has developed the inhibitory theory of boredom from a consideration of simple muscular activities. He points out that when a weight is repeatedly raised and lowered by the flexions and extensions of the finger, the ergographic tracing so obtained shows a progressive decrease in the magnitude of the contractions until further movement is impossible. If, at this stage, the weight is reduced or the muscle stimulated directly by means of an electric current, another ergogram can be readily obtained. Myers accordingly concludes that the neuro-muscular mechanism involved in this process is still capable of performing work, and that the inhibitory apparatus lies more centrally in the nervous system. Afferent impulses ascend from the tiring muscle and inhibit the initiation and transmission of further impulses to contraction, thereby acting as a protective device long before the stage of muscular exhaustion is reached.

Myers also believes that a somewhat similar protective process can be observed in monotonous mental work In the early stages of such activity attention is usually concentrated on the work in hand, and incompatible tendencies have very little effect on efficiency. As work proceeds, however, these tendencies become increasingly prominent and intrusive, attention weakens, and activity is only continued at the expense of increased effort. The feeling of boredom which arises at this stage is supposed to be a warning against the continuance of that particular occupation, and causes an impairment of the efficiency of the nervous centres connected with the initiation and distribution of impulses to activity.

Myers points out that, although many industrial processes call for very little concentration, a special "attitude" or "set" must always be maintained, and this is impaired by monotonous work. Thus boredom is regarded by him as the unpleasant feeling experienced in the process of inhibiting incompatible tendencies and in preserving the requisite "attitude" or "set," and arises whenever it is necessary to continue activity in the face of intruding desires and inclinations.

This view of boredom seems to be particularly applicable to repetitive processes in industry, in which there is usually little inherent interest, for unless perfect mechanisation of an operation is achieved, diverted attention may be prejudicial to the worker or her machine. Natural tendencies, therefore, are constantly being restrained in order that production may proceed.

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[1] "Mind and Work." London. 1920.

The foregoing hypotheses have been derived chiefly from the results of laboratory experiments, since observations on the nature of boredom in industry have as yet been incidental to other inquiries. The present report is an attempt to remedy this deficiency, and although preliminary in nature, may yet indicate lines for future research.

II. **Procedure Adopted.**

Since boredom is a subjective experience, and its precise effects on working capacity unknown, evidence of its existence must depend primarily upon introspective observation. The operatives concerned in the present investigation were accordingly questioned from time to time regarding their feelings and attitude towards their work. Their introspective evidence serves to show the presence or absence of such experiences and the relative strength of the experiences in the same individual at different times, and for this reason it has been used in the present report. We cannot, however, make quantitative comparisons between the introspections of different individuals because of the varying standards by which the judgments are made.

General subjective indications of the presence or absence of boredom having been obtained, individual work-curves were then examined to ascertain whether the boredom was associated with any characteristic variations in the rate of working. For this purpose an intensive method of observation was necessary, and minute variations in each girl's rate of working were recorded during the scheduled hours of work. The number, nature, duration, and time of occurrence of all stoppages were also noted, and the rate of working, when free from unavoidable interruptions, has been used in the statistical evaluation of the results.

The investigators were concerned with the detailed behaviour of a few workers rather than with general observations of many. This method, although it fails to yield results representative of a large sample of operatives, nevertheless discloses many important facts which are usually hidden in mass data.

Attention was usually directed to one or two operatives at a time, and the period of observation devoted to each worker seldom exceeded six days. Although this period is rather short, the close similarity of the results obtained from the same worker on different days suggests that the reliability would not have been appreciably increased by an extension of time.

The investigator sat some distance away from the worker, and, as a rule, different operatives were observed on successive days. Usually they were scarcely aware of the particular attention of the investigator. This procedure, combined with the fact that each group of workers was under observation for a period of at least six weeks, appeared to eliminate any disturbing effects which the presence of the observer might be thought to produce, for the daily output of each worker during the observational period was approximately the same as in the preceding six weeks.

After considering the general characteristics of the work-curves in relation to the introspective evidence obtained from the operatives, other symptoms of boredom, such as the tendency to overestimate time-intervals, and the increased frequency of conversations, have been discussed.

The information so obtained has been used for the purpose of exploring the particular circumstances under which boredom is likely to be experienced, and special consideration has been given to the relation between boredom and general intelligence.

Finally, the special devices adopted by the operatives for the purpose of neutralising the effects of boredom, together with other alleviating influences, have been discussed.

III. **Processes Investigated.**

(a) *Filament Winding* (" *Up-and-down* " *type*).—This operation forms one of the processes in the construction of metal filament lamps. Each girl is supplied with a tray containing 48 stems on which the filaments are to be wound. She takes a stem from the tray, and first straightens and trims the hooks, then, with a pair of tweezers, connects one end of the filament to a leading-in wire. A complete length of filament is then wound up and down, between the hooks at the upper and lower ends of the stem, and the end of the filament finally connected to the other leading-in wire as before. After being trimmed and straightened, the completed article is replaced on the tray.

The operation involves a minimum of muscular effort, but a considerable degree of finger dexterity, of sensitivity to touch, and of attention.

(b) *Filament Winding* (" *Helical* " *type*).—This process is similar to the previous, but a thicker variety of wire is used, which is supplied already cut to the correct length, and has to be looped round the hooks with a kind of circular movement. The activities involved are practically the same as those described for the previous operation.

(c) *Inserting.*—This is the name given to the process of welding the hooks into the glass stem of the lamp. The girl takes a stem in the left hand, and holds the part which is to receive the hooks in a Bunsen flame. Taking a pair of tweezers in the right hand, she picks up one of the small hooks, and inserts it into the softened glass of the stem. Other hooks are inserted in a similar manner, and the completed stem is finally replaced on the tray. This process is exceedingly delicate and exacting , it requires for its successful performance a high degree of attention, and very fine muscular co-ordination and control.

(d) *Soap Wrapping.*—In this operation the girls are seated at a table with a conveyer running along the middle, on which tablets of soap are brought from a machine. The tablets are taken from the moving belt, wrapped first in an inner wrapper of waxed paper, and then in an outer wrapper. The ends must be gummed and labelled, and the tablets packed into cardboard boxes (three tablets in a box). The box is closed and then placed on a second higher conveyer running above the first Wrappers and cardboard boxes are brought to each bench by a girl employed for that purpose.

The whole process requires some finger dexterity and light muscular effort, but is not so exacting as those previously described.

(e) *Chocolate Packing.*—In this process the girls are employed in filling ¼ lb cartons with chocolate-coated pieces of toffee. The chocolate is supplied on trays and the cartons (which are in a collapsible form) are first assembled and then lined with paper. After putting in the first layer of toffee and packing, an oblong piece of cardboard is added and the second layer of toffee completed. The addition of a little packing material completes the filling operation and the carton is then closed and placed on one side.

The operation is more varied than the inserting and soap wrapping processes, and may be regarded as a light dexterous activity.

(f) *Tobacco Weighing.*—The material for this operation is supplied in the form of large rolls (" Twist ") and the operatives work in pairs. One worker cuts and weighs the tobacco, which is then passed to the other operative to be wrapped. The rate of working is controlled by the weigher, and this was the operation observed in the present case.

Since the weighing operation has to be performed with a high degree of accuracy, the process is exacting and demands constant attention.

These comprise the processes observed in the main inquiry, but references to secondary investigations will also be found in the report.

The girls employed in the filament winding, inserting, and soap wrapping processes were paid on a piece-rate basis, but the chocolate packers and tobacco weighers were paid by time. The hours of work were from 8 to 12 and from 1 to 5.30 in the three electrical processes ; from 8 to 12 and 1 to 5 in the soap wrapping and chocolate packing operations ; from 8 to 12.30 and 1.30 to 5.0 in the tobacco weighing department.

In all the processes considered in this report, the operatives were continuously and actively engaged throughout the scheduled hours of work, and in this respect the conditions of work differ from the numerous industrial operations in which the workers are merely " minding " or " feeding " machines at intervals throughout the day.

IV. **Results Obtained.**

INTROSPECTIVE EVIDENCE.

The value of introspective evidence will obviously depend upon an accurate knowledge of particular subjective states on the part of the introspecting observer. It may be assumed, however, that most individuals are familiar with boredom, although they may sometimes confuse boredom and fatigue. A preliminary description of these experiences, together with a series of corroborative questions will, however, usually ensure distinctive replies.

When questioning operatives, it is particularly necessary to avoid the influence of suggestion, and to frame the same question in different forms in order to arrive at the truth. Operatives seldom express their thoughts or feelings with perfect freedom, unless they are no longer dependent upon the occupation as a livelihood, and the statements usually obtained probably represent an underestimation of the unfavourable elements in the conditions of work.

Laboratory Experiments.—In a laboratory experiment connected with the manufacture of bicycle-chains,[1] in which four subjects worked continuously throughout several periods of 2½ hours each, detailed introspective remarks were obtained at the end of each experimental period. The subjects were all trained in psychological research, and their remarks (Appendix I) show that boredom was experienced with some degree of intensity. It appeared to be most marked about the middle of the experimental period, and decreased when the end of work was thought to be near. On some occasions, when the subjects set out with the intention of beating their previous score, or indulged in pleasant reminiscences during the test, boredom was said to be almost entirely absent. Thus similar objective conditions may give rise to very different subjective states in the same individual at different times.

Industrial Investigations.—During the industrial investigations the operatives were frequently questioned regarding their attitude towards the conditions of work, especially in connection with the effects of uniformity. They were asked, for instance, " Are there any features which you particularly like or dislike ? " and afterwards were invited to give their views on boredom and fatigue. Relevant extracts from their replies (which are given in the Appendix) show that most of the operatives questioned suffered from boredom, especially about the middle of the work-spell. Of the 49 operatives questioned, only 13 were able to state that boredom was seldom or never experienced.

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[1] A complete description of this experiment is given in the *Journal of the National Institute of Industrial Psychology*. Vol III. No. 8. p. 406.

It is interesting to note that in the case of the tobacco weighers, boredom was said to be most marked towards the end of the morning spell, and not about the middle as in the other processes. This difference appears to be due to the recuperative effects of rest and refreshment in which the tobacco workers indulged in the early part of the morning spell.[1] In the other operations, work was continuous throughout the spell.

The replies also contain many references to devices adopted by the workers in their efforts to neutralise the effects of boredom. Among these were talking, fetching material from the stores, resting, standing instead of sitting, and walking about.

These activities indicate a desire to obtain relief from the monotonous conditions of work, but since they are often performed surreptitiously, their value to the operative may be impaired. It is interesting to note that one worker, who rested when bored, stated that it would be better if all were resting at the same time.

The replies also show that boredom is sometimes alleviated by changes in the form of work, the congenial company of the girls, and thoughts associated with external pursuits.

The ability of many of the workers to refer the experience of boredom to particular periods within the spell of work is especially fortunate, as it facilitates the interpretation of the work-curves about to be considered.

OBJECTIVE INDICATIONS.

Rate of Working.

In previous reports,[2] it has been shown that boredom has an adverse effect on rate of working, and the results obtained in the present investigation support this view. The effect is usually particularly noticeable in laboratory experiments of a prolonged and repetitive type, since, as a rule, the conditions are more exacting than in industrial work.

(*a*). *Laboratory Experiments.*

Chain-assembling.—In the course of the bicycle-chain experiments there were occasions when the subjects stated that they experienced a considerable degree of boredom, while on others the work was said to be comparatively interesting and enjoyable. The following curves (Fig. 1) have been selected to illustrate the effect of these different conditions.

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[1] The pause was usually taken about 9.30 a.m. and lasted 10 to 15 minutes. During that time the operatives ate the food which they had brought and were also supplied with tea.

[2] Reports Nos. 26 and 32 of the Industrial Fatigue Research Board.

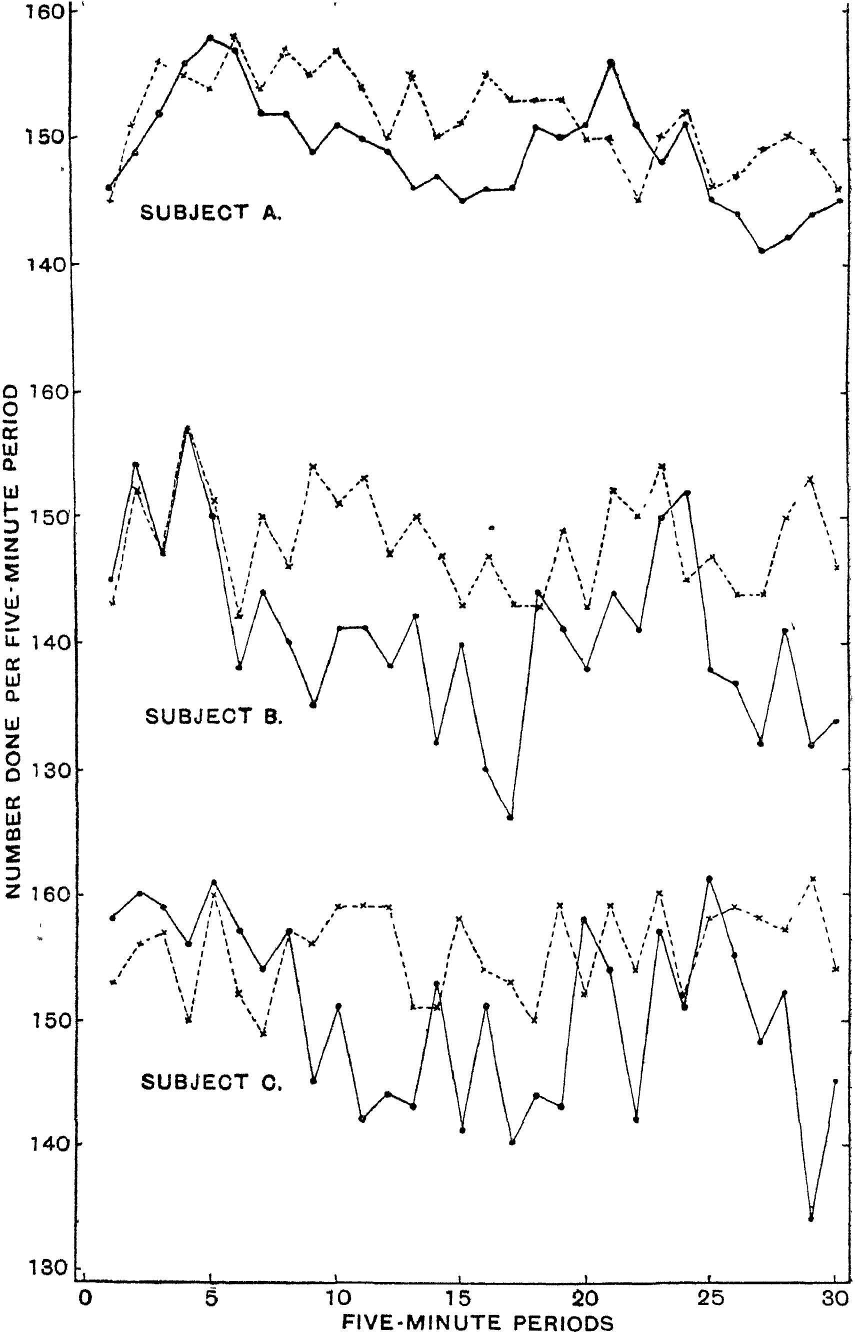

FIG. 1. Curves illustrating variations in the rate of working when boredom was experienced (continuous line) and almost absent (broken line).

Subject A.—Continuous Line.—Stated that he was very bored about the middle of the spell but recovered when he thought the end of work was near

Broken Line.—Found the work comparatively pleasant and experienced little or no boredom.

Subject B.—Continuous Line.—Began to feel bored after the first 25-30 minutes Feeling increased in intensity but disappeared when the end was believed to be near Disappointed when the signal to stop was not given

Broken Line.—Slightly bored about half-way through the spell, but on the whole time passed fairly pleasantly

Subject C.—Continuous Line.—Found the work very distasteful and was bored most of the time. Felt better near the end and thought rate of working improved

Broken Line.—Seemed to work well all the time and was less bored than usual. Conditions were a little dreary during the second hour.

It will be seen that when boredom was said to be experienced, the rate of working was particularly low about the middle of the experimental period, while the absence of boredom was conducive to a higher and more uniform rate of working throughout the spell. In the former case, however, an appreciable improvement in the rate of working occurred in the penultimate stage of work.

Rug-making.—In a rug experiment,[1] some of the curves obtained in the last two weeks also show signs of an impaired rate of working about the middle of the spell (Fig. 2).

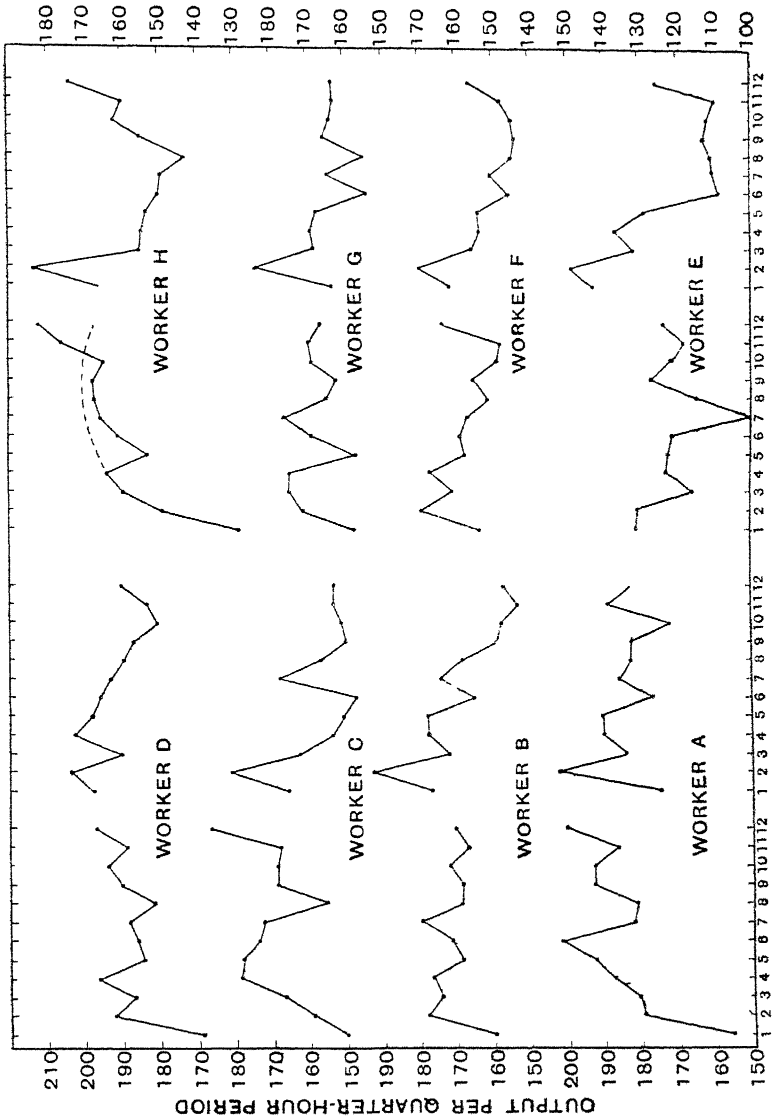

FIG. 2. Variations in rate of working during a composite day (rug-making).

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[1] In this experiment 8 girls were employed for a period of 7 weeks in making woollen rugs by inserting pieces of wool through the holes in a canvas background. The hours of work were from 9.30 to 12.30 and from 2 to 5, and the girls were paid on a piece-rate basis.

During the first hour of the morning spell the output usually continued to rise, but afterwards depressions and irregularities became increasingly noticeable. These, however, were sometimes followed by a recovery towards the end of the spell.

In the afternoon curves the fall in output began after the first half-hour of work and was usually steeper than in the morning curves.

It is evident, therefore, that working ability or inclination became noticeably impaired after the first hour in the morning spell and the first half-hour in the afternoon. One might expect, for instance, that the curve of worker H would continue along the broken line (Fig. 2). Why, in several curves, is there an abrupt change after the first 30 to 60 minutes of work, represented by a lower and more irregular rate of working and a partial recovery as the end of the spell is approached? Is the responsible factor boredom or fatigue? The answer is suggested by the results obtained in successive weeks of the experiment. If, for instance, the average output per quarter-hour period during the first hour of work is subtracted from the average output per quarter-hour period for the entire day, a comparative measure of the influence of factors detrimental to working activity is obtained. This procedure has been applied to the combined results obtained in each successive week of the experiment, and the values so obtained are given in Table I.

TABLE I.—*Difference between average output per quarter-hour period in each week and average output per quarter-hour period in first hour of work during the same experimental period.*

WORKER.	Weeks.				
	1st.	2nd.	3rd.	4–5th.	6–7th.
A	4·1	11·6	21·9	19·3	9·3
B	– 1·5	·2	5·4	– 5·4	– 1·7
C	5·2	6·8	8·2	– 2·9	·2
D	5·3	6·8	8·9	7·8	4·5
E	– 8·1	– 2·4	– 2·7	– 1·4	– 2·0
F	– 2·6	·7	1·7	·2	– 9·5
G	– 1·2	– 1·1	3·4	1·4	– 2·9
H	—	12·9	5·5	13·7	9·8
Average[1] ..	·17	3·23	6·69	2·71	– ·30

[1] Excluding the results of worker H, who began work in the second week.

During the first three weeks of the experiment the average hourly output for the whole day continued to increase above the level of that in the first hour of work, but afterwards the reverse

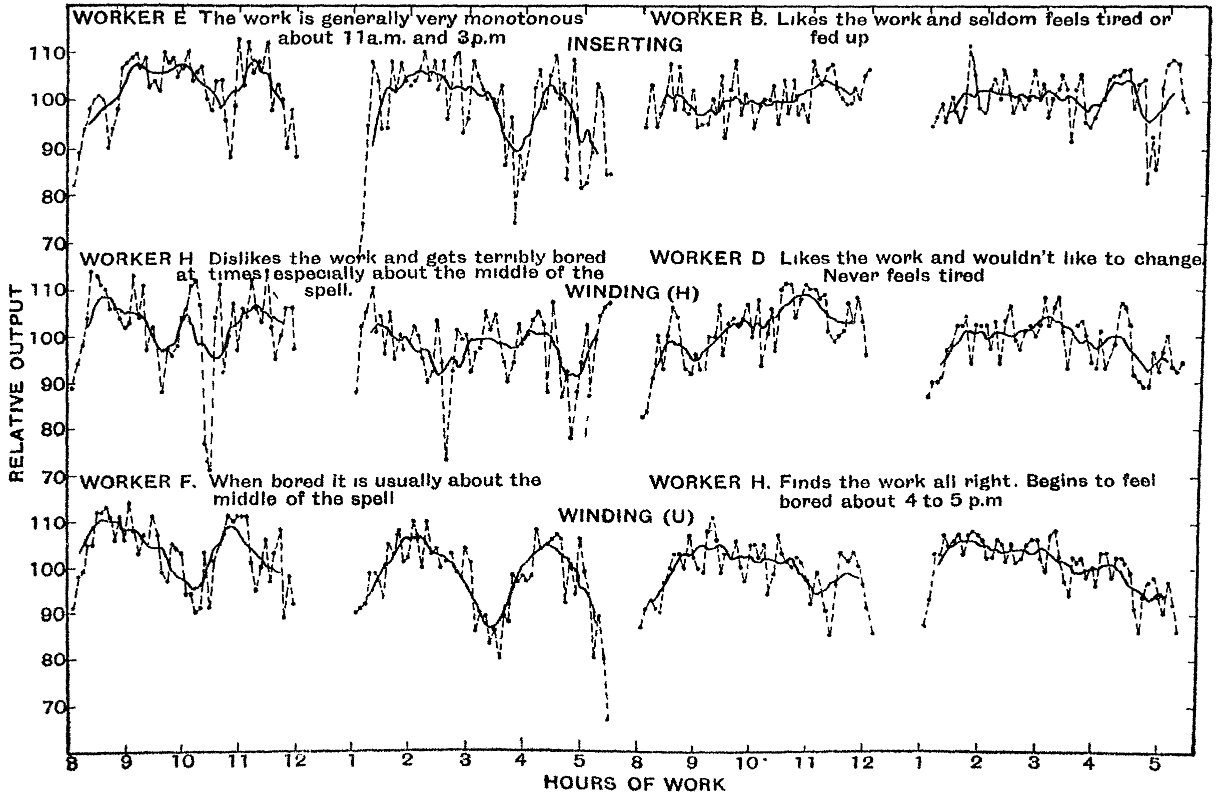

Fig. 3. Output curves obtained when boredom was experienced (left half) and almost absent (right half) in different industrial processes.

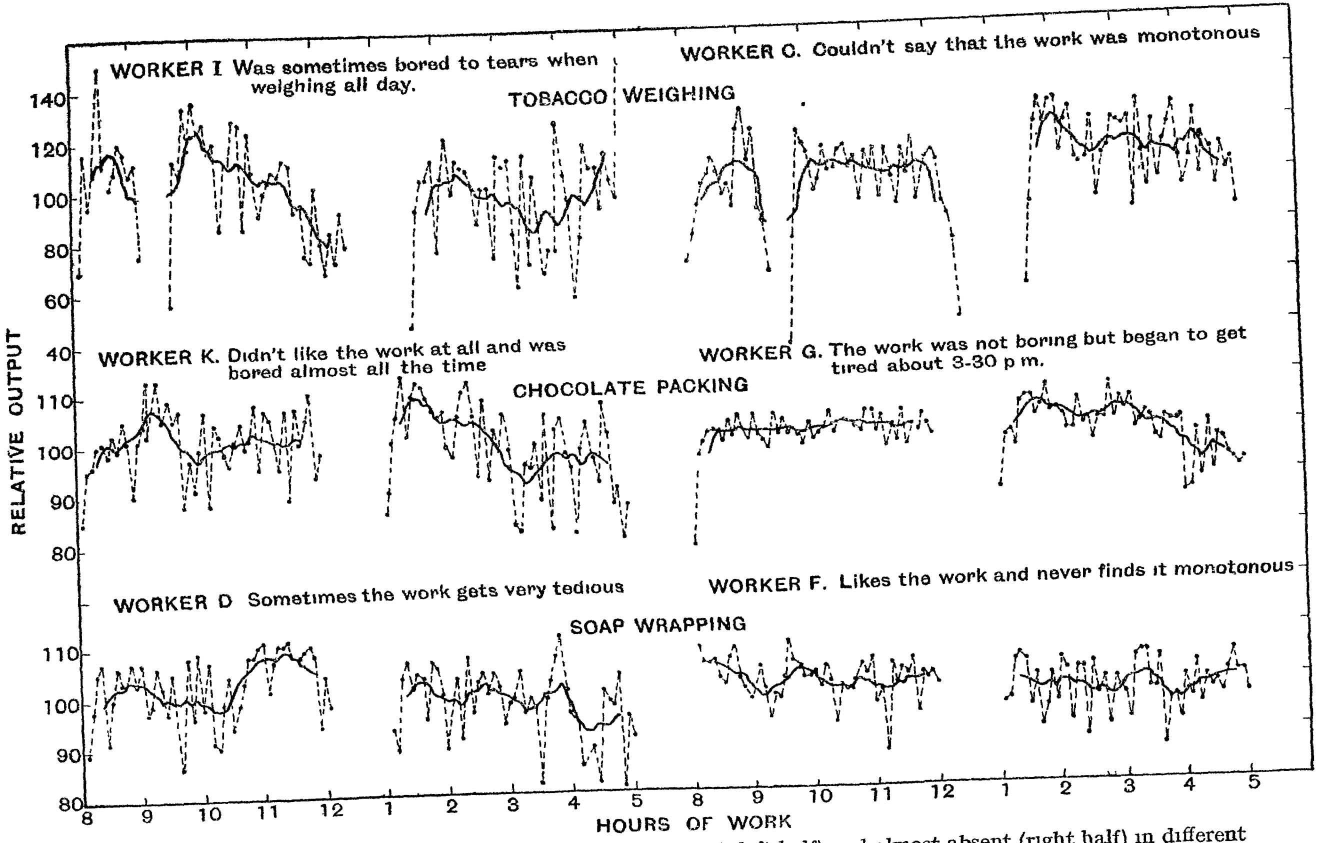

FIG. 3. Output curves obtained when boredom was experienced (left half) and almost absent (right half) in different industrial processes.

tendency was noticeable. Evidently adverse influences were at a minimum during the third week, but became increasingly effective before and after that time. It is highly probable that, in the early stages of the experiment, fatigue was responsible for the depressed rate of working, since the subjects were unanimous in their opinions that the work was most difficult and tiring at that period. "It was very hard and tiring at the beginning because you didn't know how to do it properly, but afterwards it was much easier" was typical of the opinions expressed. Boredom, on the other hand, was seldom mentioned, even when the workers were specifically questioned on this point. If, therefore, the task becomes easier in successive weeks, one would expect that fatigue, which bears some relation to the degree of difficulty experienced, would also progressively decrease. It is reasonable to believe, therefore, that the falling tendency in the results noticeable after the third week is due to the appearance of another factor. The views and general behaviour of the subjects, together with the lower rate of working frequently observed about the middle of the spell suggest that this factor is boredom.

(*b*). *Industrial Investigations.*

In the industrial investigations the results obtained from each worker at corresponding times on different days have been combined and averaged. Owing, however, to limitations of space the curves of 12 workers, two from each group, have been given, but each pair of curves is fairly typical of the results obtained in the presence or absence of boredom.

The curves (Fig. 3) represent the average rate of working during each five-minute period of a composite day (broken line) while the general trend[1] of the curves is shown by the continuous line.

Composite curves, rather than individual curves, have been given because the introspective remarks obtained from the workers represent general impressions and do not refer to any particular daily period.

A comparison of the two sets of curves shows that the experience of boredom is again associated with depressions and irregularities in the shape of the output curves, while the comparative absence of boredom is conducive to a more uniform rate of working throughout the spell.

That boredom, rather than fatigue, is the responsible factor receives additional support from a comparison of the rate of working in the morning and afternoon spells (Table II).

---

[1] Obtained by averaging the results of every seven consecutive five-minute periods.

TABLE II.—*Comparative rate of working in the morning and afternoon spells.*

Worker	Winding (U).		Winding (H).		Inserting.		Soap Wrapping.		Chocolate Packing.		Tobacco Weighing.	
	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.
A ..	102·0	98·2	101·2	99·0	100·0	100·0	101·2	98·8	99·3	100·7	93·0	109·3
B ..	102·5	97·8	104·4	96·1	100·0	100·0	101·0	99·0	99·5	100·5	101·0	98·7
C ..	101·7	98·5	102·2	98·0	99·4	100·5	100·3	99·7	97·7	102·3	97·2	103·6
D ..	99·3	100·6	101·4	98·7	102·5	97·8	102·3	97·7	100 3	99·7	102·0	97·4
E ..	99·3	100·6	102·2	98·0	102·0	98·2	101·1	98·9	101·5	98·5	101·9	97·5
F ..	103·3	97·1	103·4	97·0	100·5	99·6	101·3	98·7	101·2	98·8	104·0	94·9
G ..	97·9	101·9	101·0	99·2	—	—	—	—	100·8	99·2	99·0	101·3
H ..	99·2	100·7	102·2	98·0	—	—	—	—	100·6	99·4	103·5	95·5
I ..	—	—	—	—	—	—	—	—	97·2	102·8	104·5	94·2
J ..	—	—	—	—	—	—	—	—	97·6	102·4	98·0	102·6
K ..	—	—	—	—	—	—	—	—	98·0	102·0	—	—
L ..	—	—	—	—	—	—	—	—	100·8	99·2	—	—
M ..	—	—	—	—	—	—	—	—	102·0	98·0	—	—

When fatigue is predominant the output during the afternoon spell is usually appreciably less than that during the morning, but in the present enquiry the difference between the average rate of working in these two periods was remarkably small, and in several cases the output in the afternoon was higher than in the morning. Evidently the latter operatives were more inclined or able to work in the afternoon than in the morning, and this tendency appears to be associated with variations in attitude towards the task throughout the day.

Instances of an increased afternoon output were more frequent in the chocolate packers and tobacco weighers. These workers were paid according to time worked while in the other processes a piece-rate system of payment prevailed.

Variability.

The results obtained in the bicycle-chain experiments show that increased variability in the rate of working tends to be associated with boredom. The curves given in Fig. 1 provide an illustration of this point. In these curves the standard deviations of the five-minute readings from their daily average are :—

Subject.	*Continuous line.*	*Broken line.*
A	7·29 ± ·62	3·54 ± ·31
B	7·11 ± ·62	4·01 ± ·35
C	4·25 ± ·37	3·64 ± ·32

In the industrial investigations, an indication of the effect of boredom on rate of working is given by the curves in Fig. 3. The standard deviations of the five-minute readings from their daily average were found to be :—

Process.	Much Boredom.		Little Boredom.	
	Worker.	S.D.	Worker.	S.D.
Winding (U)	F	8·72 ± ·41	H	5·91 ± ·28
Winding (H)	H	8·31 ± ·39	D	6·39 ± ·30
Inserting	E	9·23 ± ·44	B	4·91 ± ·23
Soap wrapping	D	7·05 ± ·34	F	4·47 ± ·21
Chocolate wrapping	K	6·83 ± ·33	G	4·74 ± ·23
Tobacco weighing	I	19·44 ± ·95	C	15·31 ± ·75

In these processes also, variations in the rate of working, expressed in terms of deviations from the daily average, were appreciably greater in those workers who professed to be suffering from the effects of boredom.

In almost all the output curves obtained in this investigation a reduced rate of working appeared to be accompanied by increased variability and vice versa. In the case of the Inserters, for instance, the coefficients of correlation (*r*) between (*a*) the average rate of working during each quarter-hour of the day, and (*b*) the variations[1] of the separate observations from these averages were found to be :—

Worker.	*Coefficients of correlation.*
A	− 0·49 ± ·09
B	− 0·44 ± ·09
C	− 0·54 ± ·08
D	− 0·43 ± ·09
E	− 0·63 ± ·07
F	− 0·41 ± ·09

The above coefficients, being all negative and significant, suggest that, within the spell of work, a low rate of working tends to be accompanied by increased variability. It has already been shown that a reduction in the rate of working about the middle of the spell is symptomatic of the existence of boredom, and since a low rate of working is accompanied by increased variability, the latter may also be attributed to the same cause (when it occurs in conjunction with the mid-spell depression).

A comparison of the detailed curves obtained from different workers provides additional evidence in this connection. Two of these are given in Fig. 4, and they illustrate the type of variability obtained when boredom was experienced (curve A) and absent (curve B).

The worker responsible for curve A usually became very restless about the middle of the spell, constantly looked round, indulged in conversation with her neighbours, stretched and yawned. She remarked that the work was very monotonous, and that she often had to force herself to " carry on." The other worker stated that she liked the work and was never bored, and mentioned that she found the uniformity pleasant compared to a more varied type of process on which she was formerly engaged.

Similar curves and remarks, illustrating the presence or absence of boredom, were obtained from the other workers.

Effect on the estimated duration of time.

It is a proverbial experience that time seems to pass slowly when one is bored but appears to fly when occupations are accompanied by interest. As William James remarked,[2] " A day full of excitement, with no pauses, is said to pass ' ere we know it'. On the contrary, a day full of waiting, of unsatisfied desire for change, will seem a small eternity."

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[1] i.e., the Standard Deviation of the separate observations in each quarter-hour from their average.

[2] *Principles of Psychology.* Vol. I.

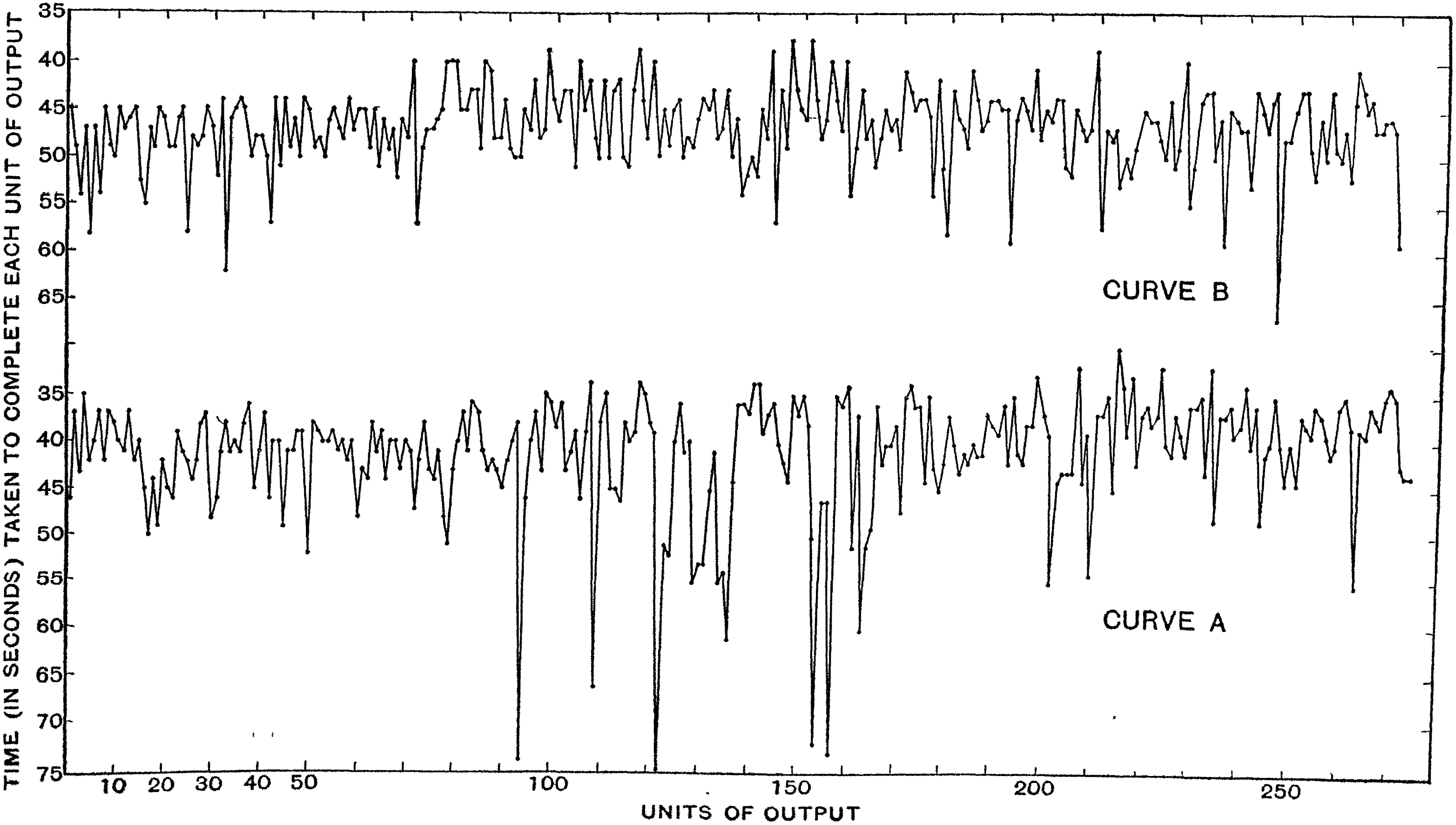


FIG. 4. Curves illustrating variations in the rate of working where boredom is experienced (Curve A) and absent (Curve B).

Examples of the illusory nature of estimates of time have been encountered in several enquiries connected with repetition work, including those which form the subject of this report.

During the course of a laboratory experiment, in which two subjects were repeatedly employed in sorting balls for a period of two hours, the experimenter asked the subject at different times within the spell of work how long he thought the work had been in progress. The following results illustrate the estimated duration of time when (*a*) the activities were said to be accompanied by a marked degree of boredom, and (*b*) the amount of boredom was said to be very slight.

			Time (in minutes).				
Subject M ..	Much boredom..	Actual	35	55	70	90	105
		Estimated	25	50	80	105	120
	Slight boredom	Actual	35	55	70	90	105
		Estimated	25	45	65	95	110
Subject S ..	Much boredom..	Actual	30	50	70	90	100
		Estimated	30	55	85	110	120
	Slight boredom	Actual	30	50	70	90	110
		Estimated	25	50	75	100	115

Although the above results refer to only two subjects, they show that when an appreciable degree of boredom was experienced the passage of time was considerably over-estimated. The over-estimation seemed to begin after work had been in progress for about an hour, and increased as the activities proceeded. Generally speaking, subject S appeared to suffer more from boredom than subject M, and in all the tests his over-estimations were greater than those of the latter subject.

The bicycle-chain experiments also provided some interesting information on the estimated flight of time. Sometimes the subjects volunteered remarks such as—

> " The end of the test came quite unexpectedly."
>
> " The word ' stop ' arrived really sooner than I expected."
>
> "The test seemed to pass very quickly ; I enjoyed the test."

While on other occasions it was said that—

> " The test seemed much longer than the specified time, and I was anxious for the end to come. I was expecting to hear the word ' stop ' about 25 minutes before it was actually called."
>
> " I expected the end at least half-an-hour before it came ; this test proved to be the most tedious of all."
>
> " The test seemed three hours in duration."

In Fig. 5 two curves are given, which illustrate the type of results obtained when the duration of the experiment appeared to be unusually long, and the introspective remarks of the subjects could be accurately assigned to particular phases within the spell of work.

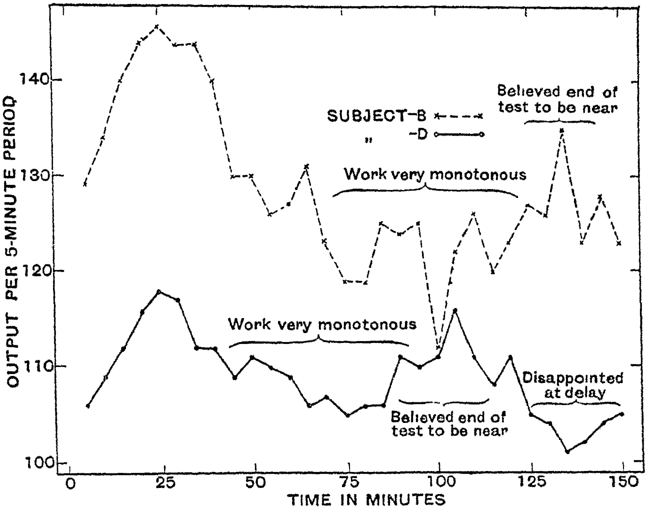


FIG. 5. Comparison of subjective states and objective results.

The depressing effects of boredom are again very much in evidence, and the notable spurts when the end of the period was thought to be near are also very marked.

In the rug experiment the subjects were asked to state which seemed the shorter, the morning or the afternoon, and afterwards to say which part of the morning and afternoon appeared to pass quickly or slowly. A summarised version of the replies is given below.

Subject.	*Replies.*
A	"The morning seems shorter and is less boring than the afternoon. The middle part of the spell appears to pass most slowly."
B	"The morning seems shorter than the afternoon. Time passes most quickly at the beginning of the spell."
C	"In the morning time passes most quickly during the last hour and most slowly about the middle, but in the afternoon the beginning of the spell seems short."
D	"The afternoon seems shorter than the morning. In the morning the last hour passes most quickly and the second hour most slowly because of boredom."
E	"The afternoon seems shorter than the morning, but work becomes dreary about the middle of both spells. In both the morning and the afternoon time passes most quickly during the first hour and most slowly during the second."
F	"The morning appears shorter and less boring than the afternoon. In both the morning and the afternoon the time passes most quickly near the beginning and most slowly about the middle."
G	"Time passes most quickly at the beginning and most slowly about the middle."

H “The last hour of the morning seems to pass most quickly and the first hour of the afternoon. The second hour is the worst.”

When the above remarks are considered in conjunction with the output curves given in Fig. 2, it will be seen that the estimated flight of time varies inversely with the rate of working. Since the depressions in the output curves are frequently associated with the experience of boredom the over-estimation of time-intervals occurs when the worker is bored.

The industrial investigations failed to provide definite evidence on the estimated duration of time-intervals, but it may be noted that many operatives expressed the opinion that time appeared to pass more quickly in the afternoon than in the morning spell of work, although the hours of work were the same in both cases. Most of these workers also stated that boredom was more pronounced in the morning than in the afternoon, and in many cases a higher output was recorded in the afternoon spell.

Talking.

Except on the rare occasions when it is prohibited, talking is a frequent accompaniment of industrial operations, though the extent to which it is indulged in naturally varies according to the tendencies of the individual workers and the conditions of work. It is, for instance, most noticeable when the operatives work in close proximity to one another, whilst it often becomes almost impracticable when the environment is noisy.

A close relation between boredom and talking has been suggested in several ways by these investigations.

In the first place the statements made by the workers indicate that talking usually occurred when boredom was experienced. “If we were never allowed to talk it would make us melancholy.” “Time passes quicker when you're talking and you don't get as bored,” “Talking doesn't help in the work but you don't get as bored,” and “When I am bored I feel like walking about or talking” were typical of the opinions expressed on such occasions, and the congenial company of the girls was often mentioned as a factor in the alleviation of boredom. Similarly, situations such as machinery noises, were said to be objectionable because they interfered with the free flow of conversation and “made talking difficult.”

Secondly, the amount of talking was by no means evenly distributed throughout the spell, and since talking is the expression of a desire, it follows that the desire varied in intensity as work proceeded throughout the day. The uneven distribution of conversation is illustrated in Figs. 6 and 7, which have been selected to show the type of results obtained. They represent the time taken to complete consecutive units of output during a spell of work, and activities accompanied by talking are denoted by the letter “T.”

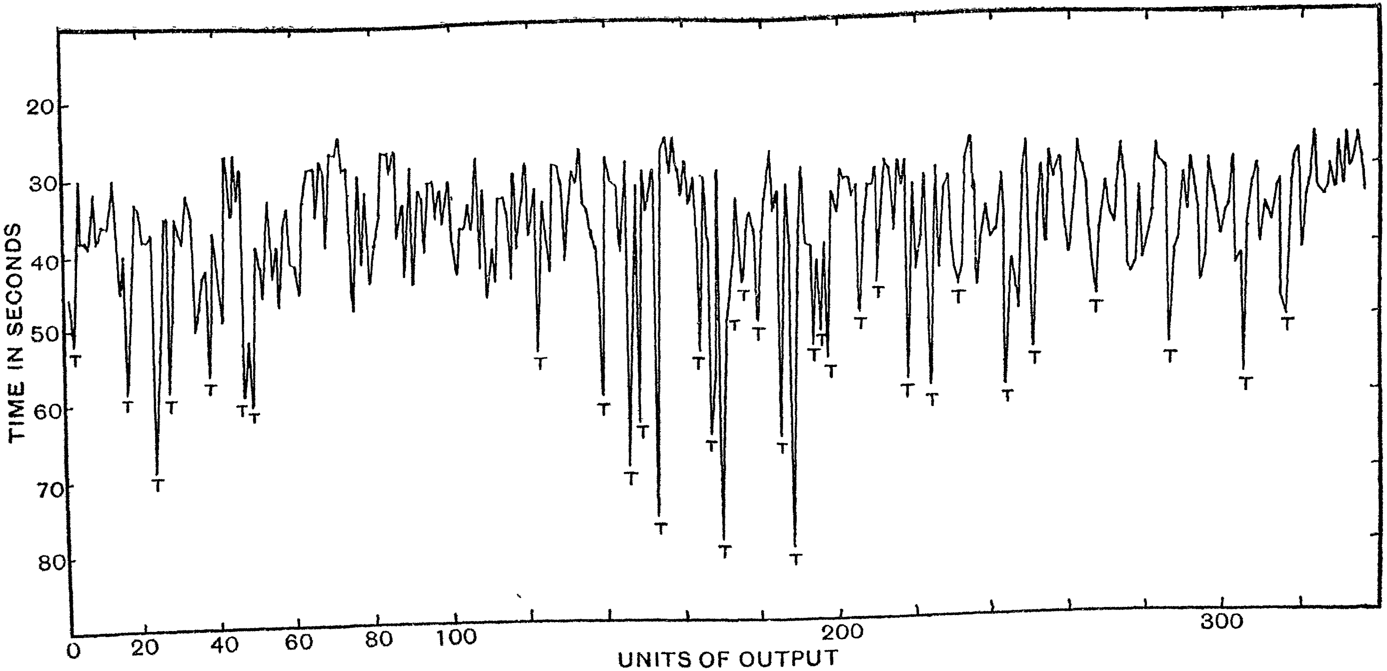


FIG. 6. Effect of boredom on time taken to complete consecutive units of output.

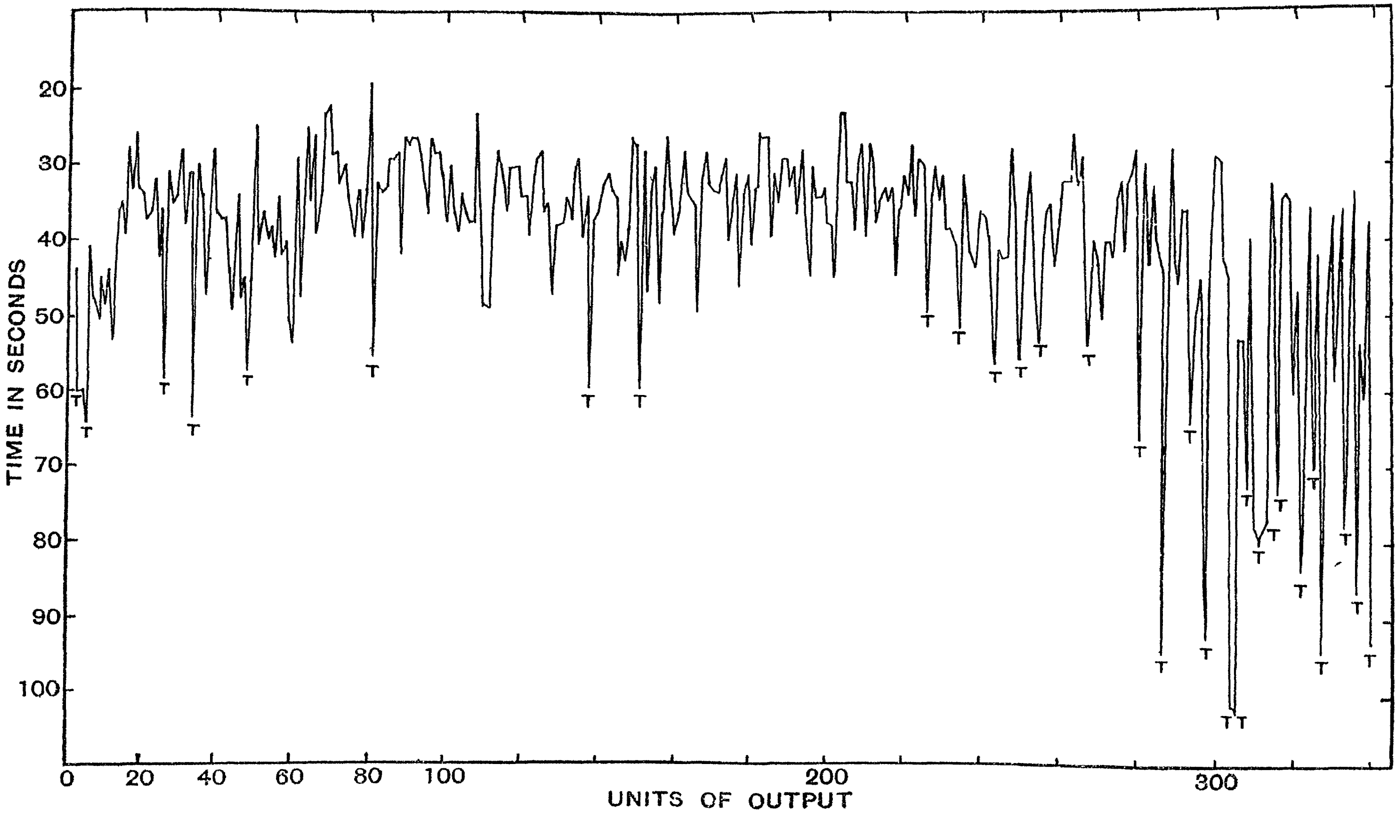


FIG. 7. Effect of fatigue on time taken to complete units of output.

It will be seen that in both cases talking was fairly prevalent at first, and appeared to be associated with the process of settlement which occurs in most forms of activity. In other respects, however, the curves differ widely; Fig. 6 shows a marked increase in frequency about the middle of the spell, diminishing as the end was approached, whilst in Fig. 7 the increase in talking is delayed until the end of the spell, when the operative presumably began to feel the effects of fatigue.

Corroborative evidence was obtained in the rug experiment, in which, during the last four weeks, talking was forbidden on alternate days. By combining the results obtained on these occasions, and comparing them with those observed during the remainder of the period, the effect of talking on output can be ascertained (Fig. 8).

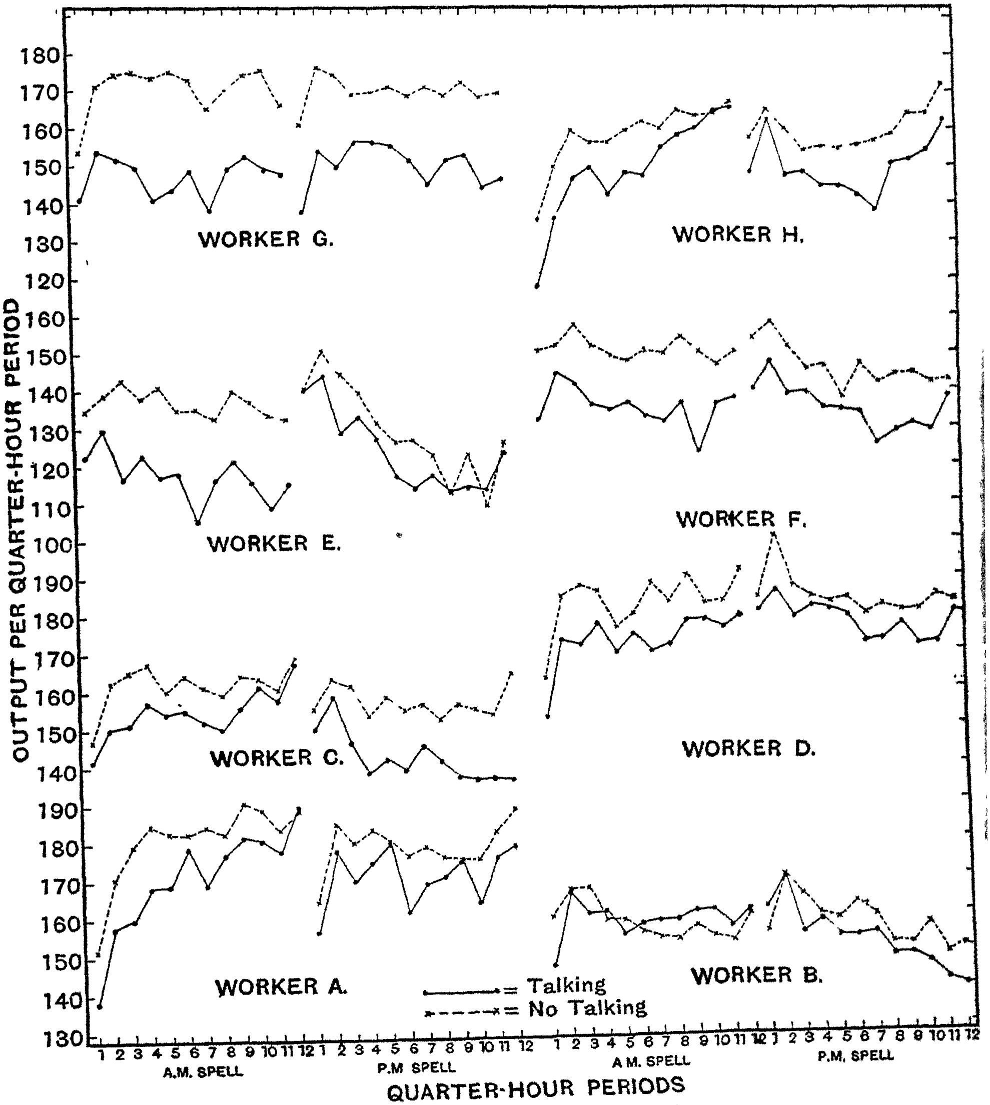


Fig. 8. Effect of talking on output.

The curves of subjects A, D, E, F and G, for instance, show that the effect of talking is most marked in the morning spell of work. In other cases there is a diverging tendency in the curves for the morning spell, but a trend in the reverse direction is noticeable in the afternoon results of subjects B and C.

It is also evident from the above curves that talking retards the rate of working. The decrease in output on days when talking was allowed varied from 4 to 16 per cent.; the average for the group being 8 per cent.

Somewhat similar results were obtained in the industrial investigations. These are given in Table III.

The percentage increase in the time taken to complete a unit of output when activities were accompanied by talking was obtained by averaging all the observations recorded when conversations occurred and comparing these with the average of the silent periods. Since talking seldom occurred during the whole of the time occupied in completing a unit of output, and in some cases may have occupied only a small fraction of this time, the total effect will not be shown in the results. These, nevertheless, reveal an appreciable impairment in the rate of working when talking occurred. It is, of course, impossible to compare the different groups of workers in this respect, because the time taken to complete a unit of output, and the portion of this time accompanied by talking varied in the different processes, and a similar though less forcible objection will apply to a comparison of the separate results within each group, because of individual differences in the rate of working.

The effect of talking on productive efficiency was almost negligible in some cases, but in others it was equivalent to a reduction in output approaching 20 per cent. This decrease was due to conversations which accompanied productive activity, but in addition there were numerous stoppages due to talking, which usually varied from 0·5 to 2·0 per cent. of the total time worked. Incidentally, it will be seen that the reduction in output due to talking was particularly notable in the processes which were paid according to time worked (i.e. chocolate packing and tobacco weighing).

The percentage of observations accompanied by talking also indicates the wide individual differences that exist in this respect. In winding (U) for instance, some workers were approximately four times as talkative as others.

Comparative considerations of this type are, of course, only approximate, and the frequency of conversation is only a crude indication of individual tendencies and inclinations. It is significant, however, that the most talkative workers were usually (though with some exceptions) those who (as shown by their introspective remarks and work curves) found work tedious. It is obvious, however, that some individuals are naturally more talkative than others, quite apart from the effect of working

TABLE III.—*Effect of talking on rate of working.* (*Industrial Investigations.*)

Worker.	Per cent. increase in time taken to complete a unit of output when talking.						Percentage of observations accompanied by talking						Per cent. equivalent loss in output.					
	Winding (U)	Winding (H)	Inserting.	Soap Wrapping.	Chocolate Packing.	Tobacco Weighing.	Winding (U).	Winding (H).	Inserting.	Soap Wrapping.	Chocolate Packing.	Tobacco Weighing.	Winding (U).	Winding (H).	Inserting.	Soap Wrapping.	Chocolate Packing.	Tobacco Weighing.
A ..	28·5	19·3	45·1	19·6	14·4	13·1	8·7	5·4	4·6	1·0	29·3	71·2	2·5	1·0	2·1	0·2	4·2	9·3
B ..	23·9	28·3	35·9	37·8	12·0	22·6	12·4	2·6	4·4	2·3	18·5	80·7	3·0	0·7	1·6	0·9	2·2	18·2
C ..	34·4	19·3	32·4	31·9	13·8	20·2	9·1	6·0	10·0	7·3	32·3	47·5	3·1	1·2	3·2	2·3	4·5	9·6
D ..	18·9	25·9	39·7	37·9	11·8	21·5	6·3	8·8	9·3	7·5	33·5	58·9	1·2	2·3	3·7	2·8	4·0	12·7
E ..	29·5	28·5	40·9	37·4	12·9	23·7	7·9	8·5	12·2	3·6	24·5	44·1	2·3	2·4	9·9	1·4	3·3	10·5
F ..	28·0	28·3	24·9	24·7	13·9	14·0	2·7	10·9	4·5	1·5	46·5	25·5	0·8	3·1	1·1	0·4	6·5	3·6
G ..	29·5	26·2	—	—	14·1	23·5	5·6	8·2	—	—	27·3	36·9	1·7	2·1	—	—	3·8	8·7
H ..	16·8	24·8	—	—	12·8	21·8	3·2	12·7	—	—	20·8	33 7	0 5	3·1	—	—	2·7	7·3
I ..	—	—	—	—	15·8	21·9	—	—	—	—	10·5	58·1	—	—	—	—	1·6	13·7
J ..	—	—	—	—	14·7	44·2	—	—	—	—	41·6	51·2	—	—	—	—	6 1	22·6
K ..	—	—	—	—	14·5	—	—	—	—	—	21·2	—	—	—	—	—	3·1	—
L ..	—	—	—	—	24·5	—	—	—	—	—	52·5	—	—	—	—	—	12·9	—
M ..	—	—	—	—	29·1	—	—	—	—	—	45·7	—	—	—	—	—	13·3	—

conditions, so that a perfect relation between frequency of conversation and the degree of boredom experienced cannot be expected.

It might be inferred that, since talking prolongs the times taken to complete a unit of output, the suppression of all conversation would produce a corresponding improvement in the rate of working and consequently an increase in output. There is little doubt, however, that talking is a powerful antidote to boredom, and should be permitted within reasonable limits. It is more wholesome than day-dreaming, and is an important factor which tends to make repetitive conditions more tolerable.

The extent to which rate of working may be affected by talking depends largely upon the type of industrial activity. Processes, for instance, which are performed automatically will be almost unaffected by conversation. Thus the amount of interference will be a rough measure of the degree of mechanisation in any process, but the results presented in Table III cannot be used for this purpose because of reasons given on page 26.

In a cigarette-making operation a more refined method of procedure was adopted in order to determine the effect of talking on rate of working.[1] On five different occasions each of the operatives was asked to work as quickly as possible for a period of five minutes in order to determine her maximum speed. On another two occasions, while working as quickly as possible, the experimenter engaged her in conversation during the entire five-minute period upon simple topics connected with the work. The average number of cigarettes completed by each operative when working at maximum speed and without conversation is given in Table IV.

TABLE IV.—*Showing the effect of talking on maximum rate of working.* (*Cigarette making.*)

Worker.	Maximum speed.		Per cent. decrease.	Worker.	Maximum speed.		Per cent. decrease.
	Without talking.	With talking.			Without talking.	With talking.	
A	23·4	20·3	13·2	K	28·9	22·1	23·5
B	23·5	21·3	9·4	L	23·3	21·4	8·2
C	27·0	23·7	12·2	M	29·5	25·5	13·6
D	25·2	19·8	21·4	N	22·0	15·9	27·7
E	26·9	22·0	18·2	O	23·3	22·0	5·6
F	28·4	24·7	13·0	P	26·5	22·0	17·0
G	27·7	21·4	22·7	Q	25·1	19·4	22·7
H	24·7	20·5	17·0	R	30·9	26·5	14·2
I	24·4	20·5	16·0	S	23·8	20·6	13·4
J	29·5	24·5	16·9	T	20·9	20·0	4·3

Average maximum rate of working without talking = 25·7.
Average rate of working with talking = 21·7.
Per cent. decrease in rate of working due to talking = 15·6.

---

[1] The cigarettes were made by hand, the operative first filling the paper tube with tobacco which she had rolled, and afterwards cutting off the ends.

The results show that when activities are accompanied by talking, the maximum speed of which the workers are capable is reduced on the average by 15·6 per cent.

DETERMINING FACTORS.

Intelligence.

The belief has sometimes been expressed that individuals endowed with a comparatively high degree of intelligence are unsuitable for simple forms of repetition work because such processes make little or no demand upon general mental ability. As a result they are said to find repetition work unsatisfying and tedious, and leave sooner or later to find employment elsewhere. Some employment managers in consequence accept for repetitive work only those individuals who are below the average in intelligence, since they find that by so doing contentment is increased and labour turnover reduced.

The relation between degree of intelligence and susceptibility to boredom has been considered in a laboratory experiment[1] in which four subjects were employed. It was found that the two subjects who ranked highest in intelligence were also the most variable in their rate of working and showed obvious signs of boredom. The other two subjects, one of whom was below the normal in intelligence, stated that they liked the work and never found it monotonous. On the basis of the introspective evidence of the subjects, their behaviour during the tests and their output curves in so far as they indicated subjective attitudes towards work, the author concluded that of the four subjects, the two most intelligent were the least suited for the work.

In the present investigation, intelligence tests[2] were given to the industrial operatives, and the combined scores in all the tests obtained by each worker are given in Table V.

TABLE V.—*Scores obtained by each worker in the Intelligence Tests.*

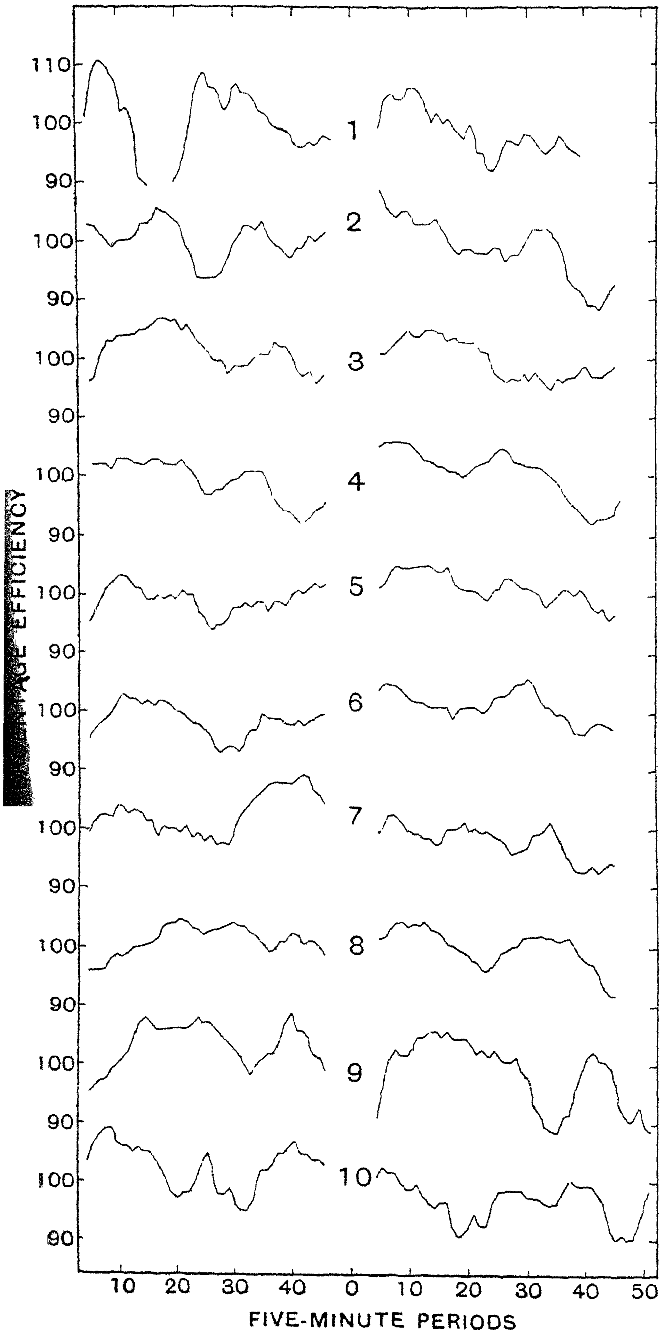
——	A	B	C	D	E	F	G	H	I	J	K	L	M
Winding (U)	76	71	56	88	74	60	36	88	—	—	—	—	—
Winding (H) ..	47	55	73	49	92	25	137	71	—	—	—	—	—
Inserting	92	52	—	95	128	99	—	—	—	—	—	—	—
Soap wrapping ..	44	30	110	118	33	17	—	—	—	—	—	—	—
Chocolate packing ..	131	40	142	125	102	73	31	67	99	—	98	96	142
Tobacco weighing ..	—	96	69	94	77	67	64	101	57	80	—	—	—

It will be seen that the intelligence scores range from 17 to 142, while the average score for all the workers is 78·5.

---

[1] Report No. 30 of the Industrial Fatigue Research Board.

[2] The tests applied were Series 33 of the National Institute of Industrial Psychology. They consisted of (1) Opposites, (2) Analogies, (3) Mixed sentences, (4) Completing sentences and (5) Reasoning. Each of the first three tests occupied 3 minutes and the last two 10 minutes each. They were given as individual, and not as group tests.



1. Worker H (Tobacco Weighing).

Intelligence = 101
Output = − 9·1
Talking = − 33·5

Bored towards end of morning and about middle of afternoon.

2. Worker M (Chocolate Packing)

Intelligence = 142
Output = − 22·1
Talking = + 47·0

Work very monotonous especially about the middle of the spell.

3. Worker E (Chocolate Packing)

Intelligence = 102
Output = + 12·6
Talking = − 21·2

Work monotonous especially about the middle of the morning

4. Worker D (Chocolate Packing)

Intelligence = 125
Output = + 4·4
Talking = + 7·7

Work sometimes tedious and uninteresting

5. Worker C (Chocolate Packing)

Intelligence = 142
Output = + 10·0
Talking = + 3·9

Tolerates the work as a means to other pursuits

6. Worker A (Chocolate Packing).

Intelligence = 131
Output = + 20·0
Talking = − 5·8

Sometimes bored in the morning about the middle of the spell

7. Worker D (Soap Wrapping).

Intelligence = 118
Output = + 7·9
Talking = + 93·8

Work sometimes very tedious.

8 Worker C (Soap Wrapping)

Intelligence = 110
Output = + 8·3
Talking = + 88·7

Work sometimes monotonous and tiring.

9. Worker E (Inserting).

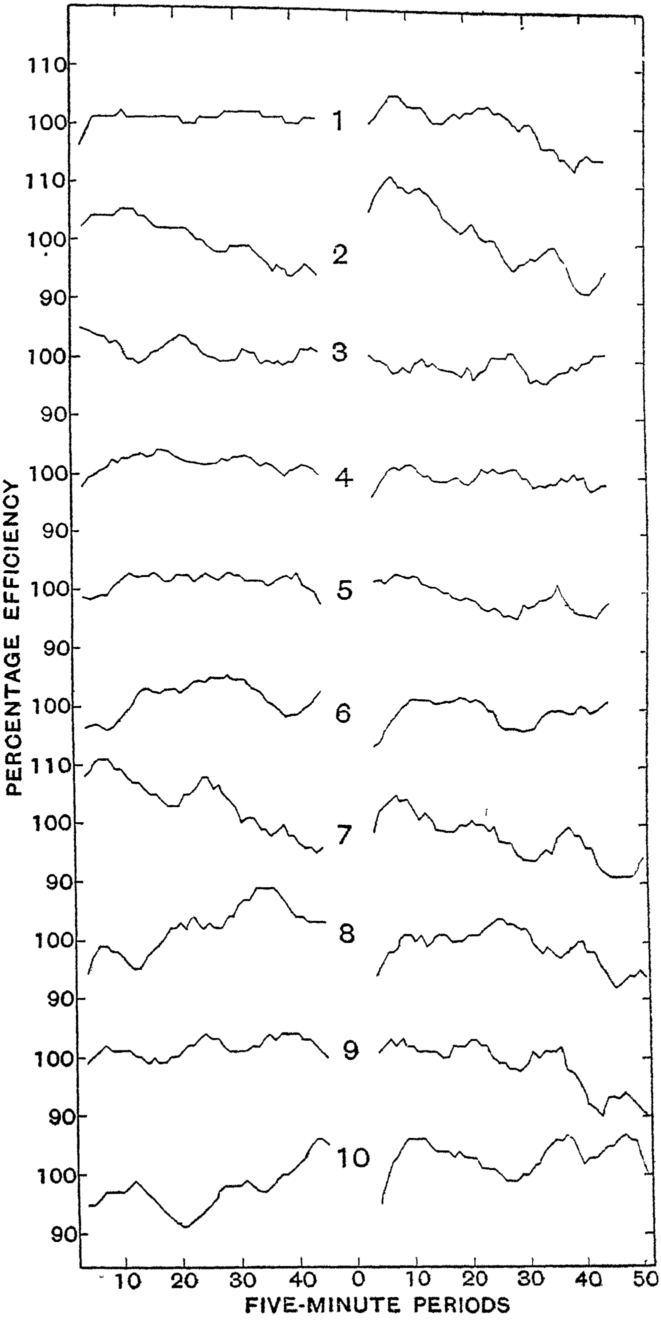
Intelligence = 128
Output = + 2·9
Talking = + 62·7

Work very monotonous about 11.0 a m. and 3 p m.

10. Worker H (Winding H).

Intelligence = 137
Output = + 19·2
Talking = + 37·1

Fig. 9. Output curves obtained from workers of superior intelligence.



1. Worker G (Chocolate Packing)

Intelligence = 31
Output = + 2·4
Talking = − 12·2

Not boring but tiring about 3 30 p.m.

2 Worker B (Chocolate Packing).

Intelligence = 40
Output = − 32 5
Talking = − 40 5

Very seldom bored except occasionally in the morning.

3 Worker F (Soap Wrapping).

Intelligence = 17
Output = − 18·8
Talking = − 61·2

Work never monotonous.

4. Worker E (Soap Wrapping).

Intelligence = 33
Output = + 9·8
Talking = − 7 0

Sometimes a little bored.

5 Worker B (Soap Wrapping)

Intelligence = 30
Output = − 2 1
Talking = − 40·6

Work very nice and not boring

6 Worker A (Soap Wrapping).

Intelligence = 44
Output = − 5·6
Talking = − 74·2

Likes the wor but sometime a little mono tonous abo the middle the afternoo

7. Worker F (Winding H).

Intelligence = 25
Output = − 9·4
Talking = + 17·7

Likes the wo but a lit tired in t late afternoo

8. Worker D (Winding H).

Intelligence = 49
Output = + 5·0
Talking = + 13·8

Never feels bor

9. Worker A (Winding H).

Intelligence = 47
Output = − 5 4
Talking = − 41·7

Likes the wo though so times fe bored.

10. Worker G (Winding U).

Intelligence = 36
Output = + 7·6
Talking = − 19·9

Sometimes bored slightly tire

FIG. 10. Output curves obtained from workers of inferior intelligence.

In order to bring out more clearly any differences which may exist between operatives of superior and inferior intelligence, a comparison of the workers having intelligence scores above 100 and below 50 has been made. This is shown in Figs. 9 and 10, which, in addition to the output curves, give—

(*a*) The output expressed as a percentage of the average for the group to which each worker belongs.

(*b*) The percentage of observations accompanied by talking, also expressed as a percentage of the Group average.

(*c*) Introspective evidence obtained from the workers.

It will be seen that the output curves obtained from the workers of inferior intelligence are steadier and less affected by the mid-spell depression than those of the more intelligent operatives. The general tone of the opinions obtained from the former group of workers is also very different from the views expressed by the more intelligent operatives; and the results as a whole indicate that, while the workers of inferior intelligence appeared to like the repetitive processes and seldom suffered from boredom, those of superior intelligence seemed to be industrial misfits and would have been better employed in occupations more suited to their abilities.

At the same time it is also evident that the more intelligent operatives were usually above the average in productive efficiency, while the less intelligent workers tended to be below the average.

Conditions of Work.

As might be expected, the experience of boredom appears to be associated with certain elements in the conditions of work. In the first place, there is evidence to show that uniformity in working procedure is more conducive to boredom than variety. This feature may be illustrated by the results obtained in the process of making cigarettes by hand, in which 20 operatives were sometimes employed throughout the day in the continuous and uniform operation of filling, while on other occasions the filling process was continued for an hour and was followed by a cutting operation.[1] The type of output curve obtained under these two methods of procedure is shown in Fig. 11.

The curve obtained on the days of uniform activity is on a lower level and somewhat different in shape from that produced under the varied method of procedure. The points marked " L " in the early part of the morning mean that output was interrupted by one or more of the girls taking lunch. Similar interruptions are not shown on the varied days because lunch was taken after the first hour of work (i.e. during the cutting process).

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[1] A complete account of the results obtained in this process is given in Report No. 52 of the Industrial Fatigue Research Board.

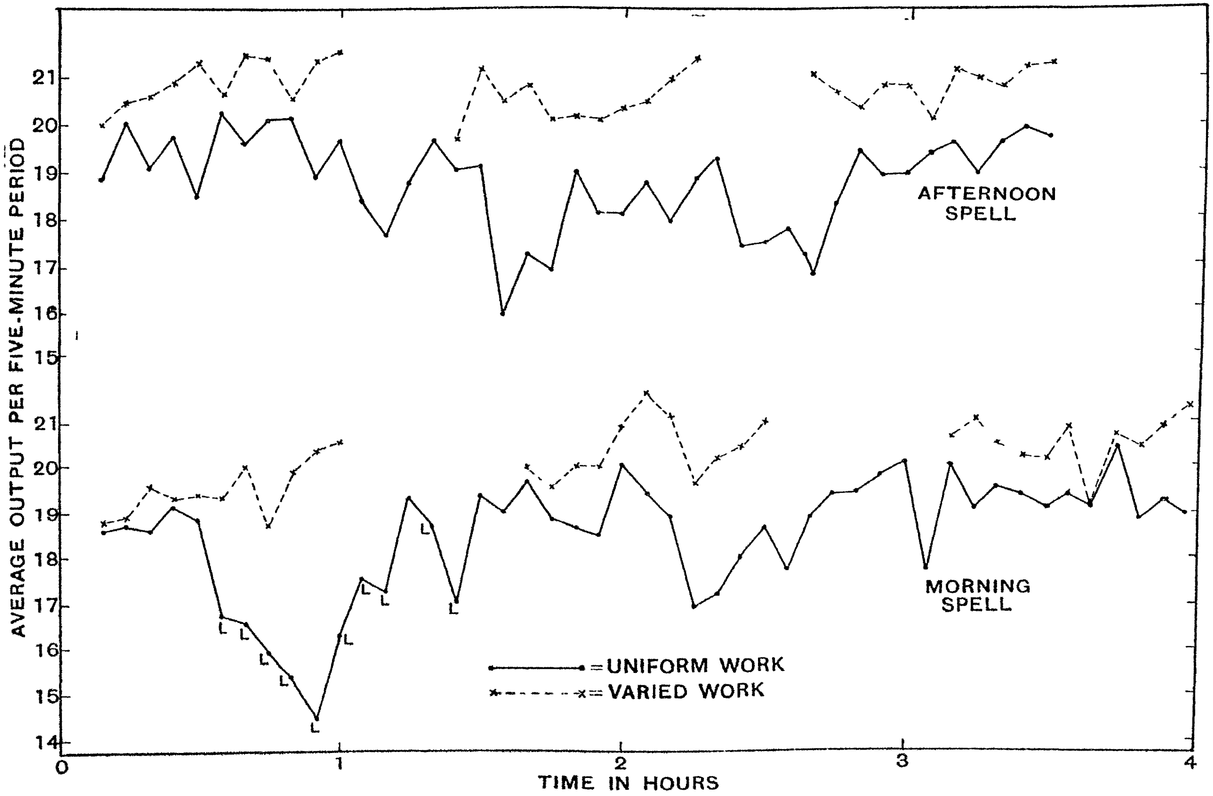

FIG. 11. Comparative rate of working under uniform and varied methods of procedure (cigarette making).

In the afternoon spell output began to decrease after work had been in progress for about an hour (uniform procedure), and, apart from temporary fluctuations, remained low until the final spurt in the last half-hour of work. These features of the curve, which are similar to those noted previously, appear to be due to the effects of boredom arising from uniformity in the conditions of work, and are very different from the less fluctuating type of curve produced by changing the form of work at approximately hourly intervals throughout the day.

It is interesting to note that the rest and refreshment in the early part of the morning spell appear to delay the onset of boredom (as shown by the depression in the curve on days of uniform work) and are even more beneficial on days of varied activity. Similar tendencies have been observed when continuous repetitive work has been broken by rest-pauses introduced at suitable times within the work-spell.[1]

In the afternoon spell signs of boredom, though slight, are still apparent about the middle of the spell on days of varied work.

Secondly, boredom appears to be more prominent when operatives are paid according to time worked rather than on the basis of output produced. In the chocolate factory, for instance, the girls, after wrapping a certain kind of chocolate for a few days, sometimes changed to a different type involving slight variations in the method of wrapping. Some of these lines were paid on a piece-rate basis while others were paid by time. The girls were asked which system of payment they preferred, and in every case they replied emphatically in favour of the piece rate. In most cases their preference seemed to be influenced by the belief that more money could be earned by the piece-rates, but it was equally evident that piece-rate remuneration provided an interest which was absent from the time-rate system. Such statements as—

> " You know that the harder you work the more money you will get on the piece-rates while on time-rates the best workers get no more money than the slow ones,"
>
> " In piece-rates you know who you are working for,"
>
> " It is pleasant to know that each box I finish means so much money at the end of the week,"

illustrate the added interest and satisfaction derived from the piece-rate system.

Another factor which seems intimately related to the amount of boredom experienced by industrial operatives is connected with the distribution of supplies. In many industrial departments the material is supplied to the workers in comparatively small quantities, while in others the supply is continuous (as in the case of soap-wrapping from a conveyer) or is handed out in sufficient quantities to last a day or so.

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[1] Reports Nos. 15, 25, and 32 of the Industrial Fatigue Research Board.

During the course of an investigation connected with the manufacture of cigarette tins,[1] the operatives were supplied with three gross at a time in order to provide a suitable statistical unit, while under ordinary conditions they received batches containing five gross. After the completion of the investigation the workers requested that the smaller and more frequent method of supply should continue as the work seemed less tedious under these conditions.

When material is supplied at approximately hourly intervals throughout the spell, the task is regarded as a self-contained unit within the larger whole. A certain amount of satisfaction is experienced as each batch is approaching completion, interest is revived, and the next batch is tackled with renewed zest. As a result the output curves for each batch show features which are similar, though less marked, to those observed in the spell as a whole. The results of the inserters, for instance, who were supplied with trays containing 48 stems which took about half-an-hour to complete, illustrate this tendency, and a fairly typical curve is given in Fig. 12. It represents the average time (in seconds) taken to complete each unit in a tray of 48 stems.

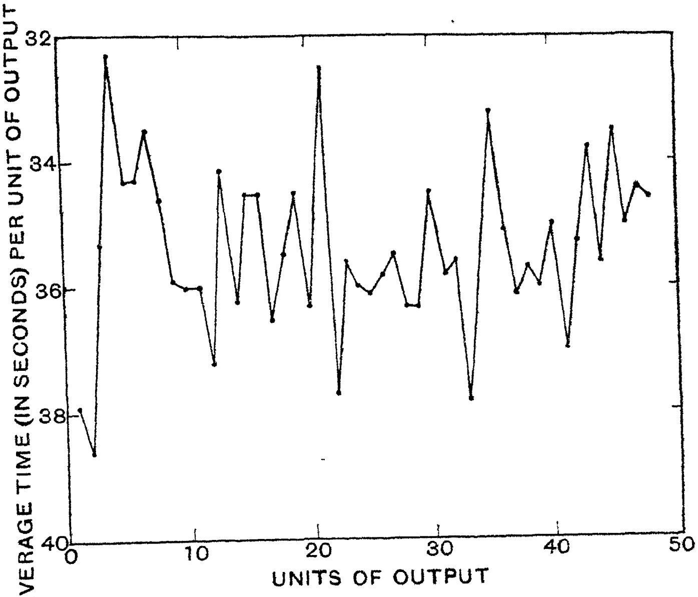

FIG. 12. Average time taken to complete consecutive units of output (Worker C. "Inserting").

In this curve the lower rate of working about the middle of the tray, together with the initial and final spurts, are clearly shown.

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[1] Report No. 32 of the Industrial Fatigue Research Board.

Most individuals have experienced the depressing effects associated with the prospect of long-continued and monotonous work, but if the task is administered in small doses some of the objectionable features appear to be reduced.

Mind-wandering.

There is evidence to show that the amount of boredom felt during repetition work is inversely related to tendencies towards mind-wandering. The existence of such tendencies is revealed by the introspective remarks obtained from the workers, especially those who formed the subjects of the laboratory experiments.

In the bicycle-chain experiments, for instance, the following views were expressed by the different subjects :—

> A. “I thoroughly enjoyed the test. Often my thoughts wandered and were concerned with my forthcoming holidays.”
>
> “My thoughts wandered extensively during the test, but strange to say I believe I worked much better during those periods.”
>
> “The occasions when my thoughts wandered were most pleasant and helped to prevent monotony.”
>
> B. “My thoughts prevented the test from becoming monotonous ; they wandered considerably.”
>
> “Interesting thoughts and pleasant reminiscences certainly help to prevent monotony in my case.”
>
> C. “When thoughts are on other matters or problems, monotony is absent.”
>
> “Occasionally I found myself theorising and not attending to the work in hand, and continued to do so until some distraction occurred. Time seemed to pass quickly and pleasantly on these occasions.”

The following curves illustrate the variations in the rate of working when (*a*) the subjects experienced boredom (continuous line). In such cases the subjects stated that their thoughts seldom wandered far from the task and the time appeared to pass unusually slowly, (*b*) boredom was almost entirely absent but mind-wandering very prevalent (broken line).

It will be seen that in the former case the rate of working was particularly low about the middle of the experimental period, while in the latter a higher and more uniform rate of working was maintained throughout the day. Evidently boredom is not experienced when the thoughts are entirely detached from the experimental task and under such conditions time appears to pass quickly.

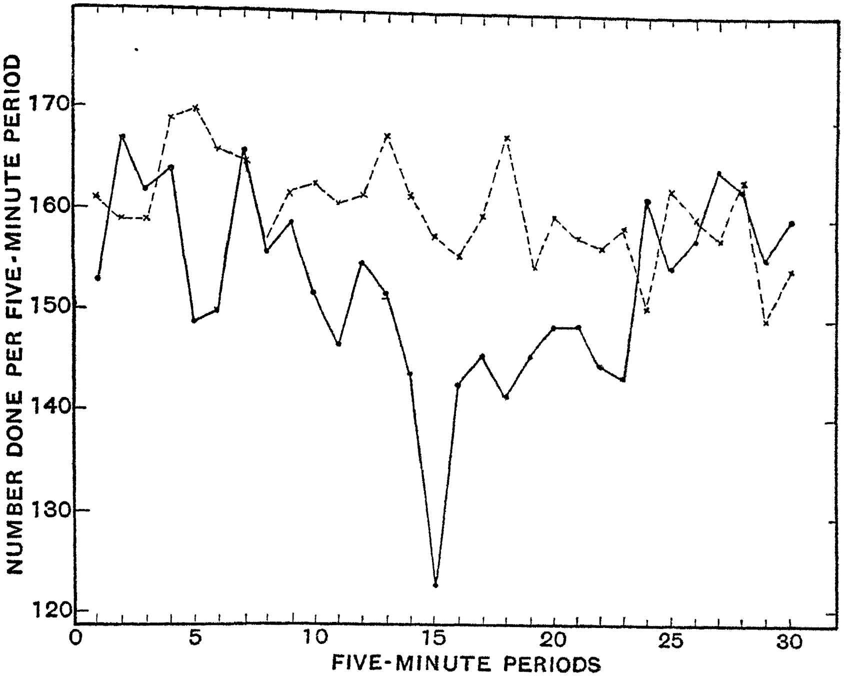

FIG. 13. Curves showing rate of working when (a) boredom was prominent and mind-wandering almost absent (continuous line), and (b) boredom was slight and mind-wandering prominent (broken line).

Adaptation.

During the course of the investigation on soap-wrapping, an opportunity arose of ascertaining the views of the operatives on the relative merits of varied and uniform conditions of work. Prior to the introduction of the process described in this report, the operatives had been engaged for several years in a similar but more varied form of activity, which included the wrapping, packing, and dispatching of 144 tablets of soap (operations lasting an hour), and involved several changes in activity and posture. The conditions of work also provided many opportunities for conversation, of which advantage was freely taken.

When the girls were first transferred to work at the conveyer, with its accompanying uniformity in posture and activity, signs of discontent and dissatisfaction were immediately evident. A deputation interviewed the manager and complained of the severe strain and tedium imposed by the new conditions of work, but after some tactful handling the girls were finally persuaded to give the method a fair trial.

When questioned individually by the investigator, each of the 30 girls considered in this inquiry expressed her dissatisfaction in unmistakeable terms.

Some two months later the same workers were again questioned, and a notable change in attitude became apparent. Each one acknowledged that the conditions were much improved, and the work less tedious and fatiguing. Some definitely preferred the new method of work, and shyly confessed that they had been rather hasty in expressing their former views.

Four months after the introduction of the conveyer the workers were still more reconciled to the modified conditions, and when asked if they would like to return to the old, 15 of the girls definitely replied in favour of the new method.

In the case of the soap wrappers, the change from variety to greater uniformity and continuity in the conditions of work involved a readjustment of the work "attitude" or "set." Although the girls, when moved to the conveyer, continued to wrap as before, the uniformity of the process constituted a new element which, at the outset, was tedious and unpleasant, because of the restricted nature of the movements involved, and the increased effort required in the maintenance of the new "attitude." The removal of the soap from the conveyer also made additional demands upon attention, and the operatives in consequence were more "bound" by the work. With practice, however, the requisite attitude was more easily maintained and attention to movements reduced, with the result that less effort was required and the operatives were better able to day-dream or talk.

It is clear, therefore, that within limits operatives are able to adapt themselves to uniformity in the conditions of work. Situations which, at the outset, may be very unpleasant because of the tedium and strain they produce, are afterwards endured without complaint, and in some cases with a certain amount of enjoyment. Because of this adaptability on the part of industrial workers, repetitive processes are made more tolerable, and the existence of boredom is not nearly so prevalent or pronounced as persons unfamiliar with industrial conditions are frequently led to believe.

V.—Discussion of Results.

The data on which this report is based were obtained from workers engaged in continuous manual operations of a repetitive type. The conclusions reached accordingly deal with a limited but important type of industrial work, but must not be regarded as applicable to other repetitive processes, such as the numerous "minding" or "replenishing" processes in which manual activity is required only at certain times during the day. Within these limits, however, the frequent presence of boredom appears to be definitely indicated, and may be due to—

(*a*) the weakening of the stimulus to work produced by the repeated performance of the same task ;
(*b*) the repression of intruding thoughts and desires ;
(*c*) the enforced effort involved in the continuation of work and in the maintenance of the work-attitude ; or
(*d*) an active feeling of repugnance to the task.

Whichever of these hypotheses is correct—and it is possible that all are involved—it is clear that boredom is a complex mental state depending on the attitude of any given worker to his work, and is accordingly related both to the nature and the conditions of the work, and also to the mentality and temperament of the individual worker.

The nature or type of industrial process is important because of its demands upon attention and thought. There is reason to believe that boredom is most likely to arise when the operatives find it necessary to give some, but not the whole of their attention to work. Processes of a semi-automatic nature, which prevent freedom of thought but are insufficient to keep the mind fully occupied, are particularly conducive to boredom. Completely automatic processes, on the other hand, enable thought to be detached from work and to follow the lines of personal interests and desires. Under such conditions the operative is able to live in a world of her own creation in which boredom can find no place. If, however, thoughts are centred on the realities of the situation, boredom may be very pronounced. At the other end of the scale there are operations demanding constant attention and varied reactions to somewhat unexpected situations. These are almost entirely non-automatic, and workers employed under such conditions have little time to dwell on the unpleasant aspects of work. Many of the processes in this category involve a considerable degree of skill, and were most prevalent in the days of craftmanship.

It is evident, therefore, that the alleviation of boredom is contingent mainly, if not wholly, on the nature and degree of the interest which the operative is able to find during work. This interest may be of two kinds. It may be relevant to the work itself, or it may be entirely external to it. The former arises when work is skilled, or comparatively free from mechanisation, but owing to industrial specialisation it is becoming increasingly rare, and is giving place to the latter kind, which is facilitated by the increasing automaticity of industrial processes. Thus there appears to be a certain degree of mechanisation which is most favourable to the development of boredom. It is important to discover this degree and then to study the attendant activities that are most likely to give relief. A further sub-division of semi-automatic processes so that they become still more automatic seems to have possibilities in this connection.

Again, the *conditions* of work, as distinct from the *type* of work, are important determinants of boredom, and are closely related to the attendant activities mentioned above. Since a contributory cause of boredom is the weakening of the stimulus to work produced by the repeated performance of the *same* task, it is obvious that some relief can be obtained by a change in the form of activity, which will revive interest and facilitate the release of energy for productive purposes. The desire for a change is frequently shown by the deliberate introduction of variations in the methods of work, and the value of organised changes has been considered in this and in other reports.[1] Rest-pauses also when introduced at suitable times within the spell of work, have similar effects (cf. p. 34), and their possibilities have been fully discussed elsewhere.[2] If, however, rest-pauses or changes in activity are impracticable, the waning incentive produced by monotonous conditions of work can sometimes be reinforced by other devices. Piece-rates, for instance, are superior to time-rates in this respect, and a progressive piece-rate would probably be still more effective. Again, enthusiasm is often damped by the prospect of an endless or overwhelming supply of material, whereas the distribution of supplies at approximately hourly intervals throughout the day is accompanied by a certain amount of pleasure in achievement and makes the worker feel that she is always " on top " of her task.

The amount of boredom experienced seems also to bear some relation to the number and proximity of the operatives employed. An isolated operative, for instance, is much more susceptible to monotonous conditions than the individuals composing a large group of operatives doing the same kind of work, when mass suggestion has greater play, conversation can be freely indulged and full expression given to " intruding thoughts and desires." Although talking usually impairs the rate of working, it is a powerful antidote to boredom and makes repetitive work more tolerable.

Finally, boredom is also associated with personal characteristics and tendencies, since different degrees of boredom are experienced by operatives employed under similar conditions of work. Of these tendencies, temperament and intelligence are probably the most important. In this investigation information on the effects of temperament was limited to observations on the behaviour of operatives while at work and during the application of special tests. It was evident, however, that the most contented, though not necessarily the most efficient, worker was of the patient, calm, and submissive type. The bright, quick, and excitable girl was usually restless and variable in her rate of working, and showed signs of being affected by the monotonous conditions of work. Since temperamental tendencies are supposed to be almost as deep-seated and persistent as the instincts, and to be intimately connected with occupational success, their investigation appears to be one of the most important problems for future research.

Similarly, the intelligent operative is bored by repetition work because it makes insufficient demands upon her abilities, just as a simple puzzle will appeal to the unintelligent but leave the more intelligent unmoved or even bored. The intelligent worker may also experience greater difficulty in repressing the more numerous and ambitious desires released by the monotonous conditions of work, but further research is necessary before these views can be definitely established.

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[1] Report No. 52 of the Industrial Fatigue Research Board.

[2] Reports Nos. 25, 32, and 42 of the Industrial Fatigue Research Board.

Indulgence in mind-wandering also depends in part upon individual differences in ability to mechanise a task. Those who are successful in this respect are better able to day-dream and enjoy any social amenities associated with the conditions of work.

It has been stated in this report that, within limits, operatives become adapted to monotonous conditions of work. Adaptation of this kind appears to be related to the causative factors mentioned in the earlier part of this discussion. In the first place, the performance of a task is facilitated by repetition. Activity becomes increasingly automatic and requires less attention and thought. A process which, at the outset, may be semi-automatic and consequently boring because of its interference with the flow of thought is afterwards performed more mechanically and ideas are able to run along more interesting lines. Secondly, repetitive work has a dulling effect on mentality. Desires and interests, which may be fairly numerous and intense during the early stages of a worker's industrial career, are weakened by routine procedure, and the operative begins to live along the lines of least resistance. Knowing that she has to remain in the factory during the scheduled hours of work, and aware that many others are in the same position, the operative philosophically resigns herself to the inevitable, and is less disturbed by conflicting desires and thoughts. In this way she is better able to endure the conditions of work, and to maintain a favourable attitude towards the task. Thus boredom is reduced by adaptation to working conditions, but the process of becoming adapted is probably not achieved without some personal sacrifice and cost.

It is evident that this investigation touches only the fringe of a subject which is becoming increasingly important in industry. Since boredom and interest are mutually exclusive, and repetitive work contains little that is inherently interesting, it is clear that attention must be focussed on the possibilities of improving conditions by—

(*a*) discovering the *type* of activity which is least conducive to boredom and modifying existing conditions so that they conform to this type ;

(*b*) changing the *conditions* of work along the lines indicated in this report ;

(*c*) studying personal characteristics and tendencies with a view to finding the abilities necessary for efficiency and contentment in repetition work ;

(*d*) increasing interest in work by means of direct or derived incentives.

VI. **Summary.**

The results obtained in this investigation may be summarised as follows :—

(1) The experience of boredom is fairly prevalent among operatives employed on repetitive processes of the type considered in this report. Of the 49 operatives concerned in this inquiry, only 13, or 26·5 per cent., were able to state that boredom was seldom or never experienced.

(2) Boredom causes a reduced rate of working which is particularly noticeable about the middle of the spell. This decrease usually lasts from one to two hours, and during that time the average reduction in the rate of working varies from 5 to 10 per cent. It is followed by a steadier and improved rate of working as the end of the spell is approached.

The lower rate of working sometimes observed in the morning spell of work, especially when the operatives were paid on a time-rate basis, is also an indication of boredom.

(3) Boredom also causes a more variable rate of working which is characterised by rapid fluctuations in the time taken to complete consecutive units of output. As a general rule a reduced rate of working is accompanied by increased variability.

(4) Boredom is also responsible for an over-estimation of time-intervals and a consequent apparent increase in the length of the working day. This over-estimation appears to be associated with a slower rate of working.

(5) The amount of boredom experienced bears some relation to the degree of mechanisation of the task. It is less liable to occur when (*a*) the work is entirely automatic. In such cases thought can be detached from work and directed to more interesting subjects, or utilised in conversation with other workers. If, however, the mind is not distracted in this manner, boredom can be very intense ; (*b*) when attention is entirely concentrated on the task. In such cases unexpected and varied situations frequently arise and the operative has no time to dwell on unpleasant features associated with the conditions of work.

It is most marked in semi-automatic processes which require enough attention to prevent mind-wandering but not enough for the complete absorption of mental activity.

(6) The experience of boredom is largely dependent upon individual characteristics and tendencies. In particular, workers of superior intelligence seem to be bored

by repetitive work. The more intelligent operatives are, however, usually above the average in productive efficiency, while the less intelligent workers tend to be below the average in this respect.

Individual differences in ability to mechanise a task, and consequently in ability to detach themselves from work, are also very marked.

Temperamental tendencies are important determinants of boredom, and need special investigation.

(7) The amount of boredom experienced bears some relation to the conditions of work. It is less liable to arise (*a*) when the form of activity is changed at suitable times within the spell of work, (*b*) when the operatives are paid according to output produced instead of time worked, (*c*) when the work is conceived as a series of self-contained tasks rather than as an indefinite and apparently interminable activity, (*d*) when the operatives are allowed to work in compact social groups rather than as isolated units, and (*e*) when suitable rests are introduced within the spell of work.

(8) Continued exposure to monotonous conditions of work causes adaptation to such conditions so that work which initially is tedious and unpleasant may afterwards be tolerated or even mildly enjoyed.

APPENDIX.

Introspective Remarks obtained from the Subjects.

LABORATORY EXPERIMENTS.

Subject A. "Usually I was able to work quite satisfactorily during the first hour but afterwards began to feel bored. At this stage the knowledge of having to stick at the job for another 90 minutes was very unpleasant, and although I tried different methods to keep the work from dragging, the efforts were not very successful. I began to feel a certain amount of relief when I thought the end of the test was near, and on such occasions had a feeling that my output improved. Shortly before the end of the period all unpleasant feelings disappeared and I felt quite normal."

Subject B. "I seldom enjoyed the tests and usually found the work tedious. The experiments often seemed very long, and after the first hour of work I experienced an impulsive desire to say something to the experimenter, or to get up and look through the window About the middle of the test I sometimes became somewhat stupefied, but towards the end began to 'sit up' and take notice."

Subject C "I usually felt bored about half-way through the test and thought 'Isn't this a rotten job' Later, however, I considered the time was passing and that the task would soon be finished At this point I felt that an increase in output began and was maintained, or even bettered, to the end of the spell. I am quite prepared to call the conditions of work monotonous, and was usually glad when the end came"

Subject D "After working for about an hour my natural inclination was to get away from the task and do something else, but I realised that it was up to me to do my best, and consequently I forced myself to continue. The increased effort experienced on these occasions was most noticeable and I was strongly tempted to slack. The work was excessively monotonous when nothing happened to distract the attention, and I welcomed the least diversion."

INDUSTRIAL INVESTIGATIONS.

Worker.	*Remarks.*
	Winding (U).
A	"I like the work fairly well but sometimes get bored. I begin to look forward to going home. Sometimes I feel like a change and go for material."
B	"I like the work as a whole but sometimes feel bored, especially in the afternoon. Then I feel like walking about or talking."
C	"The work gets tedious at times, especially about 11 a.m. I often feel like a change and sometimes take a walk."
D	"The work is very tiring, especially to the eyes I feel bored most of the time and often go to other parts of the room. I don't like the work at all."
E	"I get fed up at times, usually in the morning. I often find an excuse to walk about."
F	"Whenever I feel bored it is usually about the middle of the spell, but sometimes we do lamps of different sizes and that helps to break the boredom"
G	"There is nothing I particularly dislike, although I sometimes get bored and slightly tired."
H	"It's all right. I begin to feel bored about 4 to 5 p.m. and then I go out of the room."

Winding (H).

A I like the work very much although I sometimes feel bored, generally in the middle of the morning but occasionally in the middle of the afternoon As a rule I go out for a rest."

B I like the work all right and very seldom feel bored or want a change. I often hear the other girls say they are fed up but I never feel like that."

C " I like the company of the girls and on the whole find the work interesting The work sometimes gets tedious in the afternoon and then I feel like a change. I shouldn't like any other kind of work."

D " The work is very nice and I shouldn't like to change. I never feel bored, but if I get tired of sitting I can always find an excuse to go for material."

E " I like the work now but not when I first came. Still I look forward to going home and in the middle of the week I wish it was Saturday I sometimes make an excuse to walk about, especially in the middle of the morning and towards the end of the afternoon."

F " I like the work very much Sometimes I feel a little tired in the afternoon towards 5 o'clock, especially when I have to wait for work I could work all the time, but when there isn't work I get fed up. It would be nice to walk about sometimes "

G " The work gets tedious at times, especially about 3 p.m I sometimes feel in need of a change and although on such occasions I can leave my work it is not the same as if we were all having a rest at the same time."

H " There are no features of the work I like and I get terribly bored at times, especially about the middle of the morning and afternoon. The work is not tiring but monotonous "

Inserting.

A " The work is not so bad Sometimes I feel bored about the middle of the afternoon and would often like to move about or stand."

B " I like the work and seldom feel tired or fed up."

C (No replies obtained.)

D " I like the work more or less, but dislike many changes in the kind of lamp I sometimes feel bored, but it depends on how I feel. I usually keep on working hard all the time. Sometimes I feel like a change but try to overcome the longing. My back aches sometimes and my arms get tired "

E " The work is generally very monotonous about 11 a.m. and 3 p.m., but afterwards seems to get better. I can't say that I like the work."

F " I like the work very much. Sometimes the work seems tedious when I get tired or there is no work. Whenever I want a change I find an excuse to leave the bench. My arms and back ache sometimes."

Soap Wrapping.

A " I like the work now because it is all one thing instead of many different kinds. It is sometimes a little monotonous about the middle of the afternoon and I find it difficult to talk because of the noisy machine. The machine gets on my nerves."

B " The work now is very nice because it is always the same. It is not boring, but sometimes my back aches due to sitting in one position."

C "I used to like the old method of work because we could talk more and got to know each other better. Now we have to stop work to talk. The conditions do not allow us to be very sociable. Sometimes the work is monotonous and tiring to the shoulders and lower part of the back."

D "Sometimes the work gets very tedious, but I know that I have to work till 5 o'clock and settle down to do so. I have to stop work to talk but like the change of company obtained by working in a different position each day. Sometimes my back aches very much, especially towards the end of the spell."

E "I don't like the machinery, it gets on my nerves Sometimes I feel a little bored and often tired in my back."

F "I like the work and never find it monotonous. I get a little tired at times, especially in the arms and back."

Chocolate Packing.

A "I sometimes feel bored in the morning about the middle of the spell, but we are allowed to talk and that helps a lot. I like the days when we are allowed to change from one kind of work to another as it makes it more interesting."

B "It is very seldom that I feel bored with the work, but when I do it is usually in the morning. The days when we change are less monotonous than when we are doing the same kind of work all day."

C "I like the work as far as it goes but not from choice. The company is very congenial and we can talk when we like. My work is also only a small part of my life as I spend much time in singing and elocution."

D "Now I like the work much better than before and enjoy the company of the girls The work is sometimes tedious about 4.0 to 4 30 and I begin to get a little restless Some processes are very interesting but others are monotonous."

E "Sometimes the work is monotonous especially about the middle of the morning but never in the afternoon. I like the changes from time to time as they make the work more interesting. Packing the big fancy boxes is really enjoyable."

F "I begin to feel tired and fed up after two to three hours' work in the afternoon; it gets rather monotonous. The most interesting work is the assorted packing; sometimes it is a work of art getting them properly fitted and arranged."

G "The work is not boring but I begin to get tired about 3.30. I always wanted to do this kind of work and should not like to change."

H "When I feel bored it is usually between 10 and 11 a.m. I like the work, but I should prefer to have a shop. Some time ago I had domestic trouble and I think that is why I get dissatisfied and bored. The days when we change are the most interesting as they are less monotonous and time passes more quickly."

I "I prefer the straightforward work and dislike the assorted packing because there are too many different things to be done. Whether I feel bored or not depends on the kind of work, but when I do it is about 10.30 a.m. and 3 30 p.m."

J (Not questioned.)

K "I don't like the work at all and am bored almost all the time. When I left school I did not expect I should have to work. The conditions are better on days when we change as there is less monotony."

L "The work is often monotonous, especially when we are on the same job all the time. I feel it about the middle of the spell, and towards the end of the afternoon it is very tiring."

M "The work is very monotonous about the middle of the spell. I don't like the work, it is too dull and tedious and makes one morbid because there is too much time to think I do not intend to stay here any longer than I can help"

Tobacco Weighing.

A "I sometimes feel bored, but it depends on how I feel Usually the feeling is most noticeable towards the end of the morning and about the middle of the afternoon Still, I like the work better in the afternoon than in the morning."

B "Sometimes the work is a little tedious towards the end of the morning I don't seem to settle down in the morning while in the afternoon I usually have something to look forward to in the evening and that makes the afternoon seem shorter."

C "I can't say that the work is monotonous, but the afternoon seems shorter than the morning"

D "Whenever I feel bored I change from weighing to wrapping, but I often notice that the work is more tedious about the middle of the afternoon."

E "I never get bored, it's too lively here for that. I prefer the work in the afternoon as it seems to go quicker than the morning. I like the company of the girls"

F "The work is interesting and not at all monotonous It is like 'playing shop' The afternoons are more pleasant as they are nearer to the evenings."

G "I sometimes feel bored towards the end of the morning and prefer the work in the afternoon because time seems to pass more quickly. I often think about other things and being able to talk makes the work more enjoyable."

H "I don't like to do the same job all day without a change, as I feel bored towards the end of the morning and about the middle of the afternoon"

I "I am sometimes bored to tears when I have to weigh all day, but by changing we are able to make the work less monotonous."

J "When we are able to change from weighing to wrapping I seldom feel bored, but working on the same job all the time is very tedious and unpleasant In the afternoon I always look forward to going home as I play tennis in summer and dance almost every night in winter."

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HAMBLY, W. D., PEMBREY, M. S , and WARNER, E. C. (1925) : The Physical Fitness of Men assessed by various Methods.—*Guy's Hosp Rep.*, Oct., 1925.

Hewitt, E. M., and Bedale, E. M. (1923) : A Study of the Comparative Physiological Costs of Different Methods of Weight Carrying by Women —*Ann Rep. of the Chief Inspector of Factories for* 1922.

Hill, A V. (1927) . *Muscular Movement in Man.* New York

Hill, A V (1927) *Living Machinery* London

Hill, A. V., Long, C. N. H., and Lupton, H (1924) . Muscular Exercise, Lactic Acid and the Supply and Utilisation of Oxygen —*Proc. Roy Soc* , B. **96,** 438 , **97,** 84 , **97,** 155

Hill, A V., and Lupton, H (1923) : Muscular Exercise, Lactic Acid, and the Supply and Utilisation of Oxygen —*Quart J Med* , **16,** 62

Hill, L., Vernon, H. M , and Hargood-Ash, D (1922) . The Kata-Thermometer as a Measure of Ventilation —*Proc. Roy. Soc.*, B. **93,** 198.

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Pembrey, M S , and Others (1922) · Tests for Physical Fitness —Part I.—*Guy's Hospital Reports,* Oct , 1921. Part II.—*Ibid* , Oct , 1922.

Rusher, E. A. (1922) The Statistics of Industrial Morbidity in Great Britain —*J Roy Stat Soc.*, **85, 1.**

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Smith, May (1923) · Practical Problems of Industrial Life — ***Ind. Welfare,*** **5,** 58.

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Smith, May (1926) Industrial Psychology —*Article in Encyclopædia Britannica (XIIth Edition)*

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VERNON, H M (1923) The Causation of Industrial Accidents.—*J Ind. Hyg.*, **5,** 1.

VERNON, H. M, and BEDFORD, T (1924). The Influence of Short Time on Speed of Production —*J Nat Inst Ind Psych*, **2,** 155

VERNON, H M (1925). Can Laboratory Experiments on Output throw Light on Problems of Industrial Fatigue?—*Brit J Psych* **15,** 4.

VERNON, H M (1925). The Kata-Thermometer as an Indicator of Radiant Heat —*J. Nat Inst. Ind Psych*, **2,** 198

VERNON, H M (1925) The Work of the Tin-Plate Doubler —*J Nat. Inst Ind Psych*, **2,** 373

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VERNON, H M (1927) Ventilation in Relation to Health —*J State Med*, **34,** 683

VERNON, H M (1927). The Wet Kata-Thermometer as an Index of the Suitability of Atmospheric Conditions for Heavy Work —*J. Indust Hyg*, **9,** 287.

VERNON, H M, AND OTHERS (1926). Methods of Investigating Ventilation and its Effects —*Med Res Council Spec Rep Series No* 100.

VERNON, H M, and BEDFORD, T (1927) The Ventilation and Heating of Factories —*J Indust Hyg*, **9,** 51

VERNON, H M. and VERNON, M D (1927) The Physical and Physiological Effects of Radiant Heating by the Panel System.—*Proc Physiol Soc, J Physiol*, **64,** 1

VERNON, M D (1926): On Certain Effects of Long Spells of Repetitive Work —*Brit J Psych*, **16,** 3

WARNER, E. C., and HAMBLY, W D. (1925) An Investigation into the Physiological Basis of the U-tube Manometer Test.—*Guy's Hosp Rep*, July, 1925.

WESTON H. C. (1927) The Relation between Illumination and Efficiency in Fine Processes, with special reference to the Lighting of Printing Works —*Illum Engineer*, **20,** 221.

WESTON, H C (1927) Light and Vision in Industry —*Rep Internat. Ass for Study of Human Relations and Conditions in Industry* (Baveno), 1927

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WYATT, S (1927): Machine Speeds and Output.—*J Nat. Inst Indust. Psych*, **3,** 8

WYATT, S., and WESTON, H C (1920): A Fatigue Test under Industrial Conditions.—*Brit. J Psych.*, **10,** 4.

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Report No. 57.

MEDICAL RESEARCH COUNCIL.

INDUSTRIAL
HEALTH RESEARCH BOARD

(Formerly The Industrial Fatigue Research Board).

Further Experiments on the Use of Special Spectacles in Very Fine Processes.

By H. C. WESTON and S. ADAMS.

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Printed and Published by His Majesty's Stationery Office, and to be
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MEDICAL RESEARCH COUNCIL.

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PREFACE

For some years investigations of the visual requirements of fine processes have been conducted for the Board, with the co-operation of the Committee on the Physiology of Vision and of the Illumination Research Committee of the Department of Scientific and Industrial Research.* The results of these investigations have pointed consistently to the conclusion that while in many processes of ordinary fineness good illumination (probably higher than that usually found in practice) is alone called for, there are other processes in which the detail to be discriminated is so fine that provision of illumination, however high, does not in itself dispense with the necessity of close vision, with its concomitant strain on the muscles of convergence and accommodation.†

Relief of these two forms of strain can be secured without difficulty by the use of special spectacles with suitable lens and prism corrections, and the more recent inquiries conducted for the Board have consisted in the experimental fitting of such spectacles to operatives engaged in very fine processes and in ascertaining the opinions of these workers on the benefit to be derived from their use and the resultant change in output.

These experiments have proved encouragingly successful. In the processes studied—namely, linking in hosiery, mounting of lamp filaments, and drawing-in in weaving—the operatives have almost unanimously expressed their liking for the spectacles, whilst the effect of the spectacles on the ease of working has been shown objectively in the increase in output that has with few exceptions been associated with their use.

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* The Relation between Illumination and Efficiency in Fine Work (Typesetting by Hand), by H C. Weston, M J Inst E , and A. K Taylor M I.E.E , A.M I C E 1926 *Joint Report of the Industrial Fatigue Research Board and the Illumination Research Committee*

The effect of Different Systems of Lighting on Output and Accuracy in Fine Work (Typesetting by Hand), by H. C. Weston, M.J.Inst.E., and A K. Taylor, M I.E.E , A.M.I C E. 1928. *Joint Report of the Industrial Fatigue Research Board and the Illumination Research Committee.*

The Effect of Eyestrain on the Output of Linkers in the Hosiery Industry, by H. C. Weston, M J.Inst.E , and S. Adams, M.Sc. (1927.) *I.F R.B.Rep. No.* 40.

On the Relief of Eyestrain amongst Persons performing very fine Work. by H. C. Weston, M.J.Inst.E., and S. Adams, M.Sc. (1928.) *I.F.R B, Rep. No.* 49.

† When a near object is viewed, two muscular actions take place simultaneously, the one causing a slight rotation of the eyes inwards towards each other, thus allowing the image to fall on the same point of the retina in each eye, the other a change in the curvature of the lenses of the eyes, the object being thereby kept in focus. The former of these is known as *convergence*, the later as *accommodation*.

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One doubtful point, however, has up till now remained. The operatives selected were not originally strictly comparable in regard to vision, so that some uncertainty has always existed as to the extent to which the resulting improvement should be attributed to the correction of ordinary visual defects rather than to the special arrangements made for relieving eyestrain. In order to determine this, a further series of experiments was planned, in which the relative improvements of persons with normal (emmetropic) vision and of persons with visual defects (such as myopia and hypermetropia) after both kinds have been fitted with the special glasses could be determined.

The results of this last series of experiments are contained in the present report. It will be seen that while the benefit derived from the use of such spectacles is inevitably most appreciable where previous visual defects also have been corrected by the glasses adapted to relieve eyestrain, this benefit—whether indicated by the opinions of the operatives or by the resulting increase in output—still persists in the case of persons with perfectly normal vision, thus proving in the opinion of the Board that the use of spectacles of the kind described could be usefully extended to all operatives engaged in processes of the appropriate degree of fineness.

August 1929.

FURTHER EXPERIMENTS ON THE USE OF SPECIAL SPECTACLES IN VERY FINE PROCESSES.

BY

H. C. WESTON, M.J.Inst.E., and S. ADAMS, M.Sc.

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Introduction and General Summary of Conclusions.

The three principle experiments which form the subject of this report were undertaken with the object of determining the relative value of spectacles designed to relieve excessive accommodation and convergence when used by emmetropic* and ametropic* " close " workers.

In previous investigations† only one perfectly normal subject was available, and the use of special glasses in her case enabled the rate of output during the period covered by the investigation to be increased by three per cent. though, subsequently, much greater improvement occurred. Obviously, however, no general conclusion as to the value of such glasses to emmetropic subjects can be justified on this instance alone.

In this report thirteen emmetropes are considered. Two of these gave negative results, which are shown to be due to the influence of factors quite unconnected with the use of glasses; in three cases the improvement noted was so small as to be inconclusive, but the remaining eight all showed substantial improvement which, in no case, was less than eleven per cent. The weight of the objective evidence then is unmistakeably in favour of the use of glasses by emmetropic persons for the performance of really fine work, while the opinions expressed by the workers themselves support this conclusion.

Fifteen subjects having some error of refraction are also considered in this report. Of these, eleven had errors so slight as to be of little significance in relation to their fitness for close work. The efficiency of all the ametropic subjects was substantially increased when wearing glasses which, while correcting their errors of refraction, also reduced the amount of accommodation and convergence necessary for their work.

The average improvement of the emmetropes and ametropes was respectively 26·7 and 28·4 per cent. for ball examiners, 21·9 and 12·3 per cent. for cloth menders, 2·1 and 5·9 per cent. for linkers, and 1·3 and 4·9 per cent. for cheveners.

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* Persons having normal vision are known as emmetropes, while ametropes have some error of refraction.

† *See* Report No. 49.

Though these averages are based on a few individual results which differ considerably among themselves, they show that, in three processes, the relative improvement of the ametropic subjects was, as would be expected, greater than that of the normal persons.

With regard to the magnitude of the improvement noted in the several processes, it must be understood that the processes are not strictly comparable in respect of the demands which they make upon the visual capacities of the workers. Ball examining is the " finest " of the processes considered, the other three are roughly comparable, but the averages given for the cloth menders refer only to the most difficult portion of the work—sewing in new threads—which occupies only about twenty per cent. of the total working time. Expressed in terms of " whole output " increase, the figures for the cloth menders do not, therefore, differ greatly from those found for linkers and cheveners.

Description of Experiments and Discussion of Data.

(i) *Examining Steel Balls.*

The examination of finished steel balls for defects, such as cracks, flats and pits, demands very close visual inspection and, to the unpractised eye, some of the defects for which balls are rejected by the examiners can be seen only under the microscope. This operation, then, is one for which the use of glasses may be expected to prove beneficial.

The balls are examined in local diffused artificial light, each girl working in a hood erected on the bench so as to screen the balls under examination from other sources of light which, if reflected from the highly polished surface of the balls, would add to the difficulty of perceiving defects. The method of work is as follows :—A sheet of paper is placed on a tray about 9 in. square and supported at a convenient height and angle. A number of balls are placed on the paper, the local lamp—which is adjustable for height—is brought down within a few inches of the balls, and the whole surface of the latter is explored by moving the paper and thus rotating the balls.

The average distance of the eyes of the worker from the balls is about 9 in., and defective balls, when observed, are picked out by means of a small round bar magnet held in the right hand. It is recognised that the work is very trying to the eyes, and only candidates having 6/6 vision are employed, and these are encouraged to take rest pauses when necessary.

Four examiners were selected for experiment, but one left the works shortly after the glasses were supplied. The output of the ball examiners depends greatly on the nature of the defects found, and on the ratio of defective to good balls, as well as on the size of ball examined It was thought that the influence of these factors would be approximately the same from month to month, but this was not found to be the case.

A particular kind of defect, *e.g.*, small cracks, developed in hardening, small flats, or pin-pricks may predominate for a considerable time, particularly if the defect is one which, though developing at a late stage in the process of manufacture, owes its origin to some slight variation in the early treatment of the metal. The careful records of efficiency kept by the firm accordingly showed large variations from week to week and from month to month, and it was found impossible to form any reliable estimate of the value of the glasses worn even by comparing these records during two periods each of six months' duration.

The comparative figures presented in the following tables were, therefore, obtained by the accurate measurement of output during short periods under standardised conditions as regards the size of ball examined and the percentage of defective balls contained in the total quantities handled.

Table I gives the results obtained from the first test which was carried out on three consecutive mornings with three subjects. The examiners worked half the morning with their glasses and the other half without them, and the quantity of balls examined in each spell was measured. On the first morning glasses were worn during the initial spell, this order being reversed on subsequent mornings.

On the second and third days, therefore, it may be that the difference between output with and without the glasses is somewhat accentuated because the first period of the day—usually a relatively poor one in all industries—was worked without the aid of the glasses. On the other hand, it must be remembered that the eyes had been unaccustomed to the glasses since the end of the previous afternoon spell, whereas, on the first day of the test, the eyes became accustomed to the glasses during the first spell and the sudden withdrawal of them, besides removing a positive source of assistance, presumably entailed a period of adaptation to work without glasses which would cause a loss of output perhaps comparable to that which commonly occurs at the beginning of the first morning spell and is usually attributed to loss of " swing."

There is a notable difference between the apparent benefit derived from the glasses with one size of ball and with the others, but this may be due to the preponderant type of defect occurring in the 5/32 in. balls being more difficult to detect without glasses than the defects occurring in the other sizes of ball used during the tests.

TABLE I.

Ball Size.	Subject.	Period.	Per cent of scrap.	Relative Output.		Per cent. average difference with glasses.	Glasses used.
				No glasses	Glasses.		
$\frac{1}{8}''$	A	8—10·30	20	—	138·5	+ 23·9	A R.+1·25 sph. —0 5 cyl 2° prism L +1 5 sph. L.+0·25 cyl. 2° prism.
		10·30—1·0	20	100	—		
	B	8—10·30	20	—	117·6		
		10·30—1·0	20	100	—		
	C	8—10·30	24·2	—	115·7		
		10 30—1·0	20	100	—		
$\frac{5}{32}''$	A	8—10·30	11	100	—	+ 55·6	B R. & L. + 1·25 sph. 1·25° prism.
		10·30—1·0	11	—	157·8		
	B	8—10·30	11	100	—		
		10 30—1·0	11	—	135·7		
	C	8—10·30	11 3	100	—		
		10 30—1·0	11	—	173·4		
$\frac{7}{32}''$	A	8—10·30	10·9	100	—	+ 23·2	C R. +1·25 sph. —0·75 cyl. 1·25° prism. L. +1·00 sph. —0·5 cyl 1·25° prism.
		10·30—1·0	11·1	—	119·7		
	B	8—10·30	11·1	100	—		
		10·30—1·0	11·3	—	126·8		
	C	8—10·30	11	100	—		
		10 30—1·0	11·3	—	123·2		

All three subjects have 6/6 vision, and though two of them have a low degree of astigmatism it is very doubtful whether this defect appreciably affected their relative efficiency and susceptibility to ocular fatigue prior to its correction by the glasses

A second and more extended series of tests was made with subjects A and C using three sizes of ball and a constant percentage of scrap. These tests covered a period of five-and-a-half days, during which work was done with and without glasses in alternate spells as in the first tests. It is thus possible to compare, in the case of each subject, one composite day's work with each size of ball both with and without the aid of spectacles. Unfortunately B could not participate in these tests, as her work consisted in examining the balls passed as good by the other examiners, and her withdrawal from this occupation during the test week would seriously have affected the output of the department.

The data obtained from the tests are given in Tables II and III and show that very substantial benefit was derived from the glasses though the increases of output noted are not of the same magnitude as those observed in the first series of tests.

TABLE II.

Subject A.

	No glasses.						Glasses.					
Ball size.	% of scrap.	Period *	Kilos examd. p. hour.	Averages.		Ratio of p m to a m. output.	% of scrap.	Kilos examd p hour.	Averages		Ratio of p.m to a m. output.	% increase of output with glasses.
1/8″	15·9	1	0·48	0·56	0·59	1·16	15·6	0·76	0·79	0·84	1·20	42·4
		2	0·64					0·82				
		3	0·65	0·65				—	0·95			
		4	—					0·95				
5/32″	31·8	1	0·88	0·92	0·84	0·83	30·2	1·16	0·99	1·00	1·02	19·3
		2	0·95					0·83				
		3	0·77	0·76				0·95	1·01			
		4	0·75					1·07				
1/4″	45·4	1	3·04	3·10	3·09	0·99	44·1	3·63	3·55	3·47	0·95	12·3
		2	3·16					3·48				
		3	3·11	3·07				3·26	3·38			
		4	3·04					3·50				

* Output was measured for the following periods : 8–10.30 a.m., 10.30 a.m.–1 p.m., 2–3·45 p m., 3.45–5 30 p.m.

TABLE III.

Subject C.

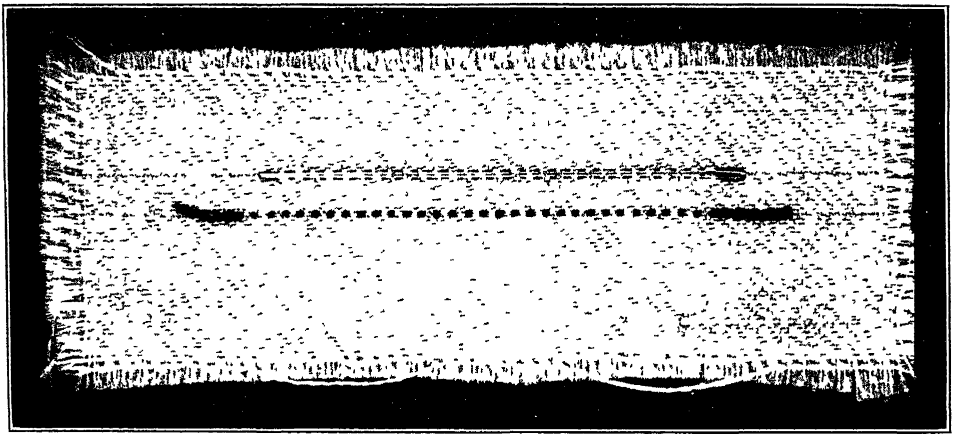
	No glasses						Glasses.					
Ball size.	% of scrap	Period.	Kilos examd p hour	Averages		Ratio of p m. to a m output.	% of scrap	Kilos examd p. hour	Averages.		Ratio of p m to a m output.	% increase of output with glasses
$\frac{1}{8}''$	14·3	1	0·74	0·74	0·80	1·15	14·3	0·86	0·88	0·91	1·06	13·75
		2	0·74					0·90				
		3	0·89	0·85				0·88	0·93			
		4	0·82					0·98				
$\frac{5}{32}''$	35·6	1	0·80	0·88	0·87	0·99	38·2	1·01	0·99	0·99	0·98	13·80
		2	0·96					0·98				
		3	0·82	0·87				0·85	0·98			
		4	0·91					1·11				
$\frac{1}{4}''$	22·7	1	2·92	2·93	2·90	0·97	23·2	3·12	3·25	3·22	0·97	11·07
		2	2·94					3·38				
		3	2·83	2·83				—	3·17			
		4	—					3·17				

The two subjects show a closely similar improvement when working with the largest size of ball, but A's output improves to a greater extent than C's when examining the smallest balls with glasses

It is evident, from the data given, that C is more skilled than A in detecting faults in the smallest balls with the unaided eye, though, with the other two sizes, both subjects appear to be of almost equal ability. The addition of glasses, however, while benefiting both workers very much to the same extent in respect of work at which both were previously equally efficient, is of relatively greater value to the less efficient worker with the smallest and most difficult work, enabling the difference between her rate of output and that of the better worker to be reduced from over 26 per cent to less than 8 per cent.

It must be observed, however, that A was provided with rather stronger glasses than C and, to some extent, her greater improvement with the finest work is doubtless due to the proportionately greater assistance she obtained from these glasses

The hourly output rate during the day shows that the higher level attained when the glasses were used did not increase the fatigue of the workers. The ratio of afternoon to morning output given in Tables II and III for each day is practically the same both with and without glasses, while there is always a " spurt " during the last spell of the " glasses day " and almost always a fall in output during the last spell of the " non-glasses day "



(ii) *Burling and Mending*

When woollen cloth leaves the loom it is passed on for burling and mending These operations are carried out by female workers who sit or stand in front of a table, the top of which can be laid flat or inclined at an angle Cloth has to be mended when threads of the warp or weft are missing, due to any failure in the working of the loom, etc Threads of the warp and weft are referred to as " ends " and " picks " respectively. The operation of replacing

" ends " and " picks " is extremely " close." The operative holds the portion of cloth which requires mending with her left hand and sews in with her right hand. The accompanying plate, actual size, illustrates the type of work and its " closeness." This particular illustration shows a portion of cloth with part of a " pick " inserted in black, and above is the needle ready to draw the yarn through part of another " pick " which requires replacing. The " closeness " of the work lies in the fact that the yarn must be replaced just as if it had been built correctly in the loom. Cloths vary in weave and therefore the operative has to vary her course with the needle. " Picks " in the cloth, similar to that illustrated in Plate " A," would be replaced with the needle travelling under two " ends " of the warp, and then over two " ends " of the warp.

Twelve operatives engaged in the operations of burling and mending were used as subjects. Their sight was tested by Mr. Harry Lee, of Leeds, and suitable glasses prescribed. Particulars of the glasses supplied are given below.

PARTICULARS OF GLASSES

Process.—Mending

Subject.	Age	Mill No.	Particulars of Glasses			
			Sph	Cyl.	Axis.	Prism Base in R. and L
D	20	1	R. +2·00 L +2·00	— —	— —	2°
E ..	19	1	R. +2·00 L. +2·00	— —	— —	2°
F	21	1	R. +2·00 L. +2·00	— —	— —	2°
G .. .	20	1	R +2·00 L. +2·00	— —	— —	2°
H	20	1	R. +2 00 L. +2 00	R. +0·50 L. +0·50	R 10 L. 180	1·5°
I	19	1	R +2·00 L. +2·00	R. +3·00 —	R. 110 —	2°
J	24	1	R +2·00 L +2·00	R. +0·50 L +0·50	R 10 L 10	1·5°
K	25	1	R. +2 00 L +2·00	R. −1·00 —	R 165 —	2°
L . ..	22	2	R. +2·00 L. +2·00	R. +0 25 L. +0·25	R. 90 L. 90	2°
M	25	2	R. +2·00 L. +2 00	— —	— —	2°
N	21	2	R +2 00 L. +2·00	— —	— —	2°
O	23	2	R. +2·00 L +2·00	— —	— —	2°

Each subject was given the choice of round or half-round glasses, and all, with the exception of H and I, selected the half-round type. The latter is preferable for this work, since clear vision with the naked eye is necessary in order to see the cloth when it is being moved over the table.

Mill No. 1.—Eight subjects were selected from this mill, four of them having normal vision and four having a low degree of astigmatism. Two " picks," each 64 in. in length, were sewn in on two separate occasions by each subject without glasses, and a similar number of picks were sewn in with the glasses in use. Thus each subject inserted 256 in. of yarn without glasses and a similar quantity with glasses, the time taken in each case being observed by means of a stop-watch. In Table IV the gross time, *i.e.* the time taken from start to finish of the sewing-in, as well as the net time spent in plying the needle is given for each operative. The operation of plying the needle requires the closest vision. The same sort of cloth was used in every case.

Mill No. 2.—Four subjects were selected from this mill, three having normal vision and the fourth slight astigmatism. Timings were obtained as at Mill No. 1, but each subject sewed in numerous short lengths where parts of picks were missing, the total length of the parts having been previously measured. Only the net mending time was obtained at this mill since each subject attended to other faults as she looked over the cloth. The timings were always taken when the same kind of cloth was being mended. In addition, each mender sewed in a continuous length of 48 in. of yarn, or more, both with and without the use of glasses, and the time occupied in each case was measured.

Mending occupies a variable, and often only a small, percentage of the total working time and, for this reason, it was considered that a more reliable measure of the value of the glasses would be obtained by adopting the method of investigation described than by comparing the rate of output of mended cloth during a control and experimental period of several weeks, or even months, duration.

Each subject filled in forms for four weeks showing the length of time she wore the glasses. In Mill No. 1 the average was

TABLE IV.

Mill No. 1.

Subject.	Time taken to sew in 128″ (Average of 2 sets of 128″)				Percentage decrease in mending time.	
	Without glasses.		With glasses.			
	Gross.	Net.	Gross.	Net.	Gross.	Net.
D	38′	29′ 35″	35′ 30″	26′ 15″	6·58	11·27
E	47′ 30″	36′ 45″	39′	29′ 32″	17·99	19 64
F	39′	31′ 30″	34′ 30″	24′ 57″	11 54	20·79
G	39′	33′ 20″	36′	27′ 43″	7·69	16·85
H	50′ 30″	33′ 25″	40′	28′ 17″	20·79	15·36
I	42′ 30″	31′ 36″	38′	28′ 16″	10·59	10·55
J	37′ 30″	28′ 11″	36′ 30″	23′ 57″	2·69	15·02
K	38′	29′ 47″	37′ 30″	28′ 26″	1·32	4·53

TABLE V.

Mill No. 2.

Subject.	Number of inches sewn in per hour. Short lengths Net in each case		Percentage decrease in mending time.
	Without glasses.	Glasses.	
L	195·5	224·1	12·76
M	197·2	237·2	16·86
N	219·2	247·0	11·26
O	175·9	296·4	40·72

Subject	Number of inches sewn in per hour. One length (48″ to 67″). Net.		Percentage decrease in mending time
	Without glasses.	Glasses.	
L	181·8	215·5	15·64
M	193·3	262 2	26·28
N	188·7	271·9	30·60
O	188·4	249 3	24 42

31 per cent., and in Mill No. 2 19·9 per cent. of the total working time, but, since it was possible to look over the top of the glasses, it is doubtful whether these figures give more than a rough idea of the time during which assistance was derived from the glasses. The data relating to Mill No. 2 are given in Table V.

In the case of every subject the use of glasses enables the time taken to do a given quantity of mending to be substantially reduced At Mill No. 1 the improvement of the emmetropes is greater than that of the astigmats, the average reductions in net time being, respectively, about 17 and 11 per cent. At Mill No. 2 the normal individuals also show the greatest improvement. The average net mending time saved by the emmetropes in both mills when wearing glasses is approximately 22 per cent. This means that, even if the glasses can only be used effectively for 20 per cent. of the work, the total output can be increased by about 4½ per cent. by their aid. From the purely economic standpoint then, the use of suitable spectacles by normal persons for this kind of work is well worth while.

(iii) *Linking Hosiery.*

In view of the assistance afforded to linkers by the glasses used in an earlier experiment* the process of linking was selected for one of the present series of experiments. The work, in this case, was much coarser (not exceeding 28 gauge) than that previously studied, but a considerable amount of dark coloured hose was linked. It was expected that the average proportion of dark work would be about the same in the two periods to be compared, but this proved not to be the case, while, owing to trade conditions, short time was worked in some weeks of the test period.

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* Described in Report No. 40.

These factors affect the rate of working, and their influence will be discussed in considering the results of the test.

Six linkers were supplied with glasses to the prescriptions of Dr. Wallace Henry, of Leicester. Four of these workers were found to be emmetropic, the fifth had a low degree of astigmatism, and the last was presbyopic and required a correction for astigmatism of + 2·5D. cyl. for each eye. Particulars of the glasses ordered are given in Table VI.

All the subjects were experienced hosiery linkers, the youngest of them having been employed on this work for three years. The work was done entirely in daylight during both the control and the test period, the linking room being lighted by roof windows of adequate dimensions.

TABLE VI.

LINKERS.

Subject.	Age	Vision	Muscles.	Glasses ordered.		
				Spher.	Cyl.	Prisms.
P ..	21	Emm	Normal.	R +1·75 L +1·75	— —	2° 2°
Q ..	26	Emm	Insufficiency 3	R +1·5 L. +1·5	— —	3° 3°
R ..	33	Emm.	Insufficiency 8	R. +2·5 L +2·5	— —	4° 4°
S ..	42	Emm.	Exophoria 0·5 Insufficiency 4	R +2·5 L. +2·5	— —	3° 3°
T ..	28	R. 6/6 L. 6/12 with cylinders	Esophoria 1·0 Normal for close work	R +1·25 L +1·25	+0·5 +1·0	1° 1°
U ..	45	R. 6/24 L. 6/9	Exophoria 1·0 Insufficiency 2	R. +3·0 L. +3·0	+2·5 +2 5	2·5° 2·5°

Records of output were obtained for a period of five weeks and, in the case of two subjects, for eight weeks, before the introduction of spectacles, and for a period of twelve weeks while the glasses were in use. After wearing their glasses for a month all the linkers were seen by Dr. Henry in whose notes, given in the Appendix to this report, their comments are quoted. Though all the subjects volunteered to take part in the experiment, three of them, Q, R and S, became rather biased against the use of glasses on account of their effect on personal appearance. T and U much appreciated the glasses and thought them very beneficial.

The percentage of dark work, the length of the working week and the average hourly rate of output during the control and test periods is given for each subject in Table VII.

TABLE VII.

Subject.	% of Dark Work.			Hours of work per week.			Hourly output in dozens.				
	Control.	Test.	Difference *	Control.	Test.	Difference *	Control	M V. ±	Test.	M V. ±	Difference. *
P ..	—	—	—	38·13	44·65	+17·1	4·14	·27	4·23	·12	+ **2·17**
Q ..	81·13	71·34	−12·1	37·06	41·04	+10·7	2·46	·07	2·51	·20	+ **2·03**
R ..	25·96	48·85	+88·2	39·23	42·73	+8·9	2·61	·15	2·43	·12	− **6·90**
S ..	—	—	—	39·76	46·81	+17·7	† 8·62	·99	† 7·43	·30	**−13·81**
T ..	21·57	15·84	−26·6	37·28	43·60	+17·0	3·80	·27	3·96	·20	+ **4·21**
U ..	22·92	16·15	−29·5	37·11	44·50	+19·9	3·94	·24	4·24	·15	+ **7·60**

* Expressed as a percentage of the control quantity. † Hourly wages.

It will be seen that two of the four emmetropes show an increase of about 2 per cent. in output during the glasses period, while there is a decrease in the case of each of the other two. The output of the astigmatic subjects is increased in both cases when the glasses are worn.

The negative results obtained with R and S do not appear to be due in any way to the glasses, but to an increase in the amount of dark work done and an increase in the number of hours worked per week during the test period. The correlation between the hourly wages earned—which vary with the rate of output—and the length of the working week and percentage of dark work has been worked out for each operative and the coefficients obtained are given in Table VIII. These coefficients show that for R and S there is a high degree of inverse correlation between the variables considered, but the coefficients are not significant in the case of the other operatives.

TABLE VIII.

Subject.	Variables.			Partial Co-efficients.
	Average hourly wages per week. (1).	Hours of work per week. (2).	Weekly percentage of dark work. (3).	
P	← + ·24 ± ·153	→		—
Q	← − ·21 ± ·156	→		—
	←	+ ·24 ± ·154	→	
R	← − ·74 ± ·077	→		
		← + ·46 ± ·133	→	$^r12 \cdot 3 = - \cdot 65$
	←	− ·65 ± 098	→	$^r13 \cdot 2 = - \cdot 56$
S	← − ·79 ± ·06	→		—
T	← + ·04 ± ·15	→		—
	←	+ ·06 ± ·15	→	
U	← + ·34 ± ·133	→		—
	←	− ·22 ± ·143	→	

The reason for this is that in the case of R, and probably also of S,* the proportion of dark work done happened to increase as the number of hours worked per week increased, whereas with the other subjects the dark work decreased as the hours increased. In the latter case, therefore, the influence of one factor was approximately neutralised by that of the other, but with R both factors depressed the rate of output during the test period. Though no accurate data regarding the amount of dark work are available for S, it is evident that the increase (nearly 18 per cent.) in the number of hours worked per week during the test period is sufficient to account for a considerable fall in the hourly rate of production of this worker.

There are two reasons why the number of hours worked may be causally related to the speed of work. In the first place, an increase of hours may involve additional fatigue and thus bring about a reduction in the average speed of work and, secondly, a reduction of hours may induce a higher speed of work in order that the total weekly wage earned may not fall much below the sum which the worker is accustomed to earn when on full time.

The latter reason is probably the principle one in this case for, though the variation of hours was sufficient appreciably to affect the total weekly wage if the rate of working had remained constant, the daily variation was so small that it is unlikely that fatigue would be sensibly increased or decreased by it.

Reverting to the results of subjects P and Q, the improvement noted in the test period is small, and, it must be admitted, of doubtful significance when the reliability of the averages compared (as indicated by the mean variations) is taken into consideration. Q did not wear her glasses continuously, and the variability of her rate of output during the test period may be partly due to this.

So far, however, as the emmetropes are concerned the objective results of this experiment afford inconclusive evidence of the value of the glasses. The opinions of subjects P, R and S are definitely in favour of the glasses, and they would not now like to dispense with them. Q, while admitting that she can see her work better when wearing the glasses, appears to be quite comfortable without them. Subjects P, T and U all experienced headaches before they were provided with glasses, but have since had no trouble in this respect.

Other Experiments.

(iv) *Filing Fish-hooks.*

The operation of filing by hand the barbs on small fish-hooks is one which calls for considerable skill and very close visual inspection. Three thoroughly experienced filers, working on the smallest types of hook, who expressed their willingness to wear glasses, were examined for us by Mr. E. B. Alabaster, of Birmingham. All three were found to have errors of refraction and particulars of the glasses supplied to them are given in Table IX.

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* Owing to the variable character of her work, which consisted chiefly of jerseys and pullovers of various patterns, the relative amount of dark linking is difficult to determine accurately.

TABLE IX.

Subject.	Glasses.		
	Spher.	Cyl	Prism.
X	R −1·5 L. +2·0	— − 1·0 axis 170°	1·5° 1·5°
Y	R +0·75 L. +0·75	− 0·5 axis 90° —	1·0° 1·0°
Z	R. +4·75 L. +4·75	— − 0·75 axis 100°	1·0° 1·0°

Records were obtained of the piece-rate earnings of these workers during a period of three months before the glasses were provided, and again for a further period of three months while the glasses were in use. The average hourly wage earned in each period is given in Table X, and is considerably higher for the glasses than for the pre-glasses period. In the case of the presbyopic subject Z a very serious loss of efficiency, much of which is doubtless due to visual incapacity, is characteristic of the pre-glasses period.

TABLE X.

Subject.	Hourly Wages.				Difference.
	No glasses	M.V. ±	Glasses.	M.V. ±	
X	12·25	0·89	12·94	1·01	+ 5·63 %
Y	10·65	0·96	11·35	0·76	+ 6·57 %
Z	12·30	1·21	18·32	1·81	+48·94 %

As there was some reason to believe that output in this process would be subject to a seasonal effect, records of wages earned were also obtained for three months in the year preceding the introduction of glasses and for the same three months in the year following the provision of the glasses, i.e. when the latter had been in use for approximately twelve months. The average hourly wages in these two periods are compared in Table XI and again show the favourable influence of the glasses.

TABLE XI

Subject	Hourly Wages.				Difference.
	No glasses	M.V. ±	Glasses	M.V ±	
X	13·07	1·18	15·12	0·93	+15·68 %
Y	12·10	0·42	13·02	0·46	+ 7·60 %
Z	15·88	1·96	18·02	2·42	+13·47 %

A comparison of the figures given in columns 4 and 6 of Table X with those of the same columns of Table XI is interesting. These figures refer to the same period of two succeeding years when glasses were used, the improvement of two of the men in the second year being greater than in the first. On the other hand, if the figures in column 2 of Table XI are compared with those of column 4 of Table X—the first series referring to the three summer months of the year preceding the introduction of glasses and the second series to the same months of the year when glasses were first worn—no improvement is apparent, except in the case of Z. Since, however, it was impossible to determine whether the period in the year prior to the investigation was strictly comparable, in all relevant respects, with the corresponding periods when glasses were used, the evidential value of these comparisons must remain doubtful.

The principal evidence adduced, that of the data given in Table X, and relating to periods comparable except in respect of temperature, leaves, however, little room for doubt as to the value of the glasses to the workers concerned or as to the loss of efficiency for which defective vision may be responsible when fine work is done.

(v) *Chevening by Hand.*

The results of an early experiment made with four cheveners are included here as showing that even weak glasses, without prisms, may be of assistance to close workers, and especially to those having slight errors of refraction. Chevening is the process of embroidering designs, or " clocs," on hosiery, and it demands very close vision. Most of the chevening done by the subjects of this experiment was carried out on dark-coloured hose with silk or artificial silk of various colours. The design is worked by following the whales or needle loops of the hose lengthwise, and the course or row of loops on the circumference.

Work is done with the hose stretched over the left hand and held about seven inches from the eyes.

The wages (based on the number of stitches made) earned by each of the operatives were obtained for a period of three weeks without glasses and for a similar period with glasses, both periods being comparable in respect of the type of work (designs) done. Particulars of the glasses supplied to each worker are given in Table XII, and the number of stitches done per hour during each period is given in Table XIII. In each case output improved when the glasses were worn, though, in the case of the emmetropic subject No. 2, the improvement is scarcely significant. All the operatives liked the glasses, and considered them decidedly helpful.

TABLE XII.

Subject.	Glasses.		
	Spher.	Cyl.	Axis.
1	R. +1·75 L. +1·50	−0·25 −0·25	180 180
2	R. +1·50 L. +1·50	—	—
3	R +1·25 L +0·75	—	-
4	R. +1·00 L +1·00	—	—

TABLE XIII

Subject.	Stitches per hour.				Difference.
	No Glasses.	M V. ±	Glasses.	M V. ±	
1 ..	1565	268 = 17 %	1638	204 = 12·4 %	+ 4·63 %
2 ..	1736	260 = 15 %	1759	240 = 13·6 %	+ 1·31 %
3 ..	1027	141 = 13·7 %	1089	171 = 15·7 %	+ 6·01 %
4 ..	1402	89 = 6·4 %	1461	132 = 9 %	+ 4·23 %

General Considerations Concerning the Prescription and Use of Spectacles for Fine Work.*

The distance at which clear vision is possible when using spectacles designed for very close work is naturally limited and, when distant vision is necessary, glasses with round or full oval lenses must be taken off or moved away from the eyes to permit vision over the top of them. Unless distant vision is likely to be required for fairly long periods, neither of these expedients is desirable, and it is better to use lenses the top half of which is sufficiently flattened or cut away to allow the worker to see over the top of them while the glasses are in situ if the eyes are raised from the work.

In most cases, oval lenses having a horizontal axis 37·5 mm long, and a vertical axis of 30 mm., flattened at the top so that the actual vertical measurement is 23 mm., will be found suitable. If the vertical dimension is reduced below this figure, reflection of light from the top of the frames into the eyes of the worker becomes objectionable. If the major portion of the work is fine enough to make the use of strong spheres (+ 3 or 4D) desirable, but clear vision is frequently required at various distances on the bench, both in front and at the sides of the worker—for example for the purpose of selecting material—it may be advisable to use bifocal in preference to flat-topped lenses.

If greater magnification is required than can conveniently be obtained by spectacles worn in the usual way close to the eyes, special frames may be used, the bridge of which rests on the tip of the nose, thus positioning the lenses, which are made smaller than usual, about an inch and a quarter in front of the eyes Such glasses are sometimes used by surgeons for dissection, and for delicate operations upon the eye, and though somewhat unattractive in appearance, they could be used with great advantage for some industrial operations.

For the ordinary type of spectacles the question of frames is not unimportant. Some fine work is done in a fairly hot and humid atmosphere and, in these circumstances, steel frames should not be used, as they quickly rust and break. Frameless spectacles are not to be recommended for factory use. They are fragile and do not lend themselves to accurate angling—an important point—so well as do framed spectacles.

The cost of the spectacles depends, of course, partly on the material used for the frames as well as on the lenses ordered. If, however, a number of pairs are required, as will often be the case, most opticians will probably supply them at a specially reduced rate and the average cost per pair, in nickel frames, should not then exceed about fifteen shillings. The results of the experiments described in this and previous reports show that the cost of the glasses, on the above basis, can be recovered in the shape of additional wages in a few weeks or, at the most, in a few months.

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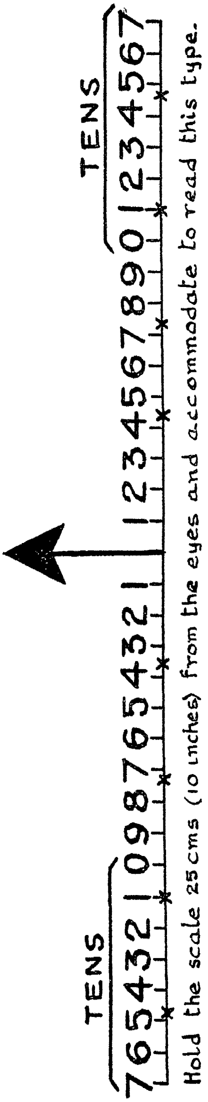
* " Fine work," for which glasses may be useful, is defined in Report 49, Part I, as work the details of which, when adequately illuminated, cannot be clearly seen unless the eyes are brought within ten inches of it.

The comfort of the glasses and the absence of unpleasant sensations, as of " drawing " the eyes, depends largely on the combination of suitable prisms with the spherical lenses used. Many people have latent insufficiency or excess of convergence at reading distance which is not apparent, or is much less pronounced, when viewing objects at a distance of several yards. In examining " close " workers it is not, therefore, sufficient to apply the usual test for heterophoria, using a Maddox rod and scale at a distance of six metres. The muscle action must be tested at approximately the customary working distance, for which purpose the Maddox wing test, or a special scale viewed with a strong prism held base up before one eye, is suitable.

Though the prescription of the actual glasses required in any given case should always be left to an ophthalmologist, a preliminary examination of workers selected for fine processes could be made by the Works Welfare Superintendent using Snellen's test types, at a distance of six metres, for visual acuity, and either of the muscles tests just referred to. A suitable scale is reproduced on page 25. If this is viewed with both eyes at a distance of 25 cm. with a 12 degree prism held base up before one eye two scales and arrows will be seen one above the other. If the arrows appear both to be in the same vertical line there is no insufficiency or excess of convergence but, if the lower arrow points to one of the figures on the upper scale to the left of the top arrow this figure indicates the degree of insufficiency present. Similarly, if the lower arrow points to a right-hand figure on the upper scale, this will indicate the degree of excess of convergence. If the deviation in either direction is five, or more, headaches are likely to be experienced if much really close work is done without prismatic assistance.

When glasses are used to assist accommodation these will tend to increase the discomfort due to the deviation described above if prisms of adequate strength are not combined with the lenses. Two cases in point (not among our experimental subjects) have come under our notice. These workers obtained glasses with + 2 D. spheres, but were advised by the optician (who applied only the Maddox rod test) that they did not need prisms. They complained that the glasses " drew " their eyes and discarded them on account of the discomfort experienced. On applying the Maddox wing test to these persons they were found to have insufficiency of convergence of 6 and 14 respectively.

The advisability of normal persons using glasses such as those employed in the experiments described in this report has occasionally been questioned on the ground that the use of some measure of artificial accommodation and convergence might tend to impair the natural functional capacity of the eyes and render the continuance of artificial aid indispensable. This objection appears to be groundless for, in our experience, workers who have worn the spectacles designed for their special work during factory hours have often found themselves able to do close work, such as



Hold the scale 25 cms (10 inches) from the eyes and accommodate to read this type.

sewing, in the evening without the glasses, and without experiencing the discomfort and strain which such work previously entailed when attempted after a day's work in the factory with the unaided eyes.

It must be realised that to maintain accommodation and convergence at or near the possible maximum for long periods, or for short periods of very frequent occurrence, as is necessary for doing very fine work, is not itself a natural procedure, nor one for which the ocular muscles are particularly adapted, any more than other groups of muscles are particularly adapted for the long continued exercise of a maximal effort. Outdoor workers, such as agricultural labourers and seamen, whose eyes are, for by far the greater portion of their working time, focussed for distance, do not, so far as we are aware, lose their power of accommodation more readily than " close " workers who exercise this power much more. While it is true that such persons might find it difficult so readily to see certain fine details which are quickly seen by the close worker, this is due not to any diminished power of accommodation and convergence but to the absence of that special " sense " or facility for discrimination which experience and long familiarity with small objects develops in the close worker.

No complaints of any undesirable effects attributable to the spectacles supplied to the linkers who formed our original experimental subjects have arisen, although these spectacles have now been used for three years. On the contrary, the experience of these workers has led others in the same factory recently to obtain similar glasses.

APPENDIX.

Notes by R. WALLACE HENRY, M.D.

I have seen each of the six linkers, about whom I send a detailed report, on three occasions. They all greatly like the glasses ordered and find them a great help in their work. Most of them think they can do more work, but say that, owing to the varied character of the materials on which they are engaged, it is very difficult to give a very definite answer on this point.

I do not think that it is possible to suggest a standard glass for all workers, as the strength of the prism required must depend to a large extent on the presence or absence of Exophoria or insufficiency of convergence Roughly speaking, the addition of + 1·75 D. spher. with prism 2° base in each eye would suit cases which are Emmetrop icand have normal muscle action. A similar addition would be of considerable assistance in all cases that have normal muscle action for close work, irrespective of their refraction. Should there be Esophoria a reduction in the prism corresponding to the amount of overaction of the Internal Recti would be necessary. Should there be insufficiency of convergence, an addition of the strength of the prism to neutralise this would be of advantage.

There are many simple instruments, which could be used by practically unskilled persons, by which the action of the muscles for close work could be ascertained, and the necessary prism to be added could be found by rule of thumb in most instances, and a prescription for these with + 1·75 D. spher. added could be given.

Report on Linkers Examined.

P.—Age 21. Worked as a linker for three years. Vision 6/5 each eye. No muscular defect. Some headaches

Ordered + 1·75 D. Spher. with Prism 2° base in each eye.

Would not like to give them up. Sees much more clearly. Headaches very rare now.

Q.—Age 26 Has worked as a linker for 9 or 10 years

Vision 6/5 each eye. Has a trace of myopic astigmatism. Insufficiency of convergence 3

Ordered + 1·5 D Spher. with Prism 3° base in each eye.

Says she could see to do her work all right without glasses but sees much better with them.

R.—Age 33 Has worked as a linker for 15 years.

Rt vision 6/9. Lt. vision 6/6.

Emmetropic. Insufficiency of convergence 8.

Ordered + 2·5 D. Spher each eye with Prism 4° each eye.

Says they are a great help at her work and would not be without them. I had great difficulty in persuading her to wear glasses ; now as she is getting better frames she is very anxious lest she should be without her present glasses while new ones are being made

S.—Age 44 Has worked as a linker for 30 years

Vision 6/5 each eye Emmetropic. Exophoria 0·5. Insufficiency of convergence 4

Ordered + 2·5 D Spher with Prism 3° base in each eye.

Finds them a decided help and would not like to be without them.

At first she had much trouble with them as part of her work is at a longer distance, and other workers in the room say that she was very fond of looking round the room to see what was going on, she has now apparently given this up and, as stated, finds the glasses a decided help.

T.—Age 28. Worked as a linker for 8 years. Severe headaches.

Rt. Vision 6/6 = 6/6 with + 0·5 D. Cyl. axis 90.

Lt. Vision 6/12 = 6/6 with + 1·0 D. Cyl axis 90.

Esophoria 1. Muscles normal for close work. Ordered + 1·25 D. Spher. with Cyl. and Prism 1° base in each eye.

Finds a big improvement. Does more work. Has no headaches, and would not like to be without the glasses.

U.—Age 45. Has worked as a linker for 31 years. Some trouble at work (owing probably to Presbyopia for past few years).

Rt Vision 6/24 improved to 6/9 with + 2·5 D. Cyl. axis 110.

Lt. Vision 6/9 = 6/9 with + 2·5 D. Cyl. axis 67·5.

Exophoria 1. Insufficiency of convergence 2. Ordered + 3 D. Spher. with Cyls. and Prism 2·5° base in each eye.

Finds them a great help and would not be without them.

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A.—MINING INDUSTRY.

No. 39.—The Relation of Atmospheric Conditions to the Working Capacity and Accident Rates of Miners.

No 51 —A Study of Absenteeism in a Group of Ten Collieries.

B.—METAL AND ENGINEERING INDUSTRIES.

No. 1.—The Influence of Hours of Work and of Ventilation on Output in Tinplate Manufacture

No. 2 —The Output of Women Workers in Relation to Hours of Work in Shell-making.

No. 3.—A Study of Improved Methods in an Iron Foundry.

No. 5.—Fatigue and Efficiency in the Iron and Steel Industry.

†No. 6.—The Speed of Adaptation to Altered Hours of Work.

No 15.—Motion Study in Metal Polishing.

C —TEXTILE INDUSTRIES.

No. 7 —Individual Differences in Output in the Cotton Industry.

No. 8 —Some Observations on Bobbing Winding.

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No. 17.—An Analysis of the Individual Differences in the Output of Silk-Weavers.

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No. 21 —Atmospheric Conditions in Cotton Weaving.

No. 23 —Variations in Efficiency in Cotton Weaving.

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*No 49 —On the Relief of Eyestrain amongst Persons Performing very Fine Work.

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† A short account of the principal practical conclusions reached up to 1924 will be found in Report No. 27 (Results of Investigations in Certain Industries) *see* p. 30.

D.—BOOT AND SHOE INDUSTRY.

No. 10 —Preliminary Notes on the Boot and Shoe Industry
No 11 —Preliminary Notes on Atmospheric Conditions in Boot and Shoe Factories
*No. 25.—Two Contributions to the Study of Rest Pauses in Industry.
*No 26 —On the Extent and Effects of Variety in Repetitive Work
*No. 35 —A Physiological Study of the Ventilation and Heating in Certain Factories

E —POTTERY INDUSTRY.

No. 18 —Two Investigations in Potters' Shops.

F —LAUNDRY INDUSTRY.

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No. 30 —An Experimental Investigation into Repetitive Work
No. 32.—Studies in Repetitive Work with special reference to Rest Pauses
No. 52 —The Comparative Effects of Variety and Uniformity in Work.
No. 56.—The Effects of Monotony in Work (A Preliminary Inquiry).

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Cathcart, E P , Bedale, E M , and McCallum, G (1923) : Studies in Muscle Activity —I The Static Effect —*J Physiol.*, **57,** 3 & 4.

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Culpin, M. and Smith, M (1928) : Sickness Absenteeism · a preliminary study.—*Brit. M. J.* 21st July, 1928

Dickinson, S (1928) : The Dynamics of Bicycle Pedalling.—*Proc. Roy Soc* B, **103,** 225

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GREENWOOD, M, and NEWBOLD, E M (1923): On the Estimation of Metabolism from Determination of Carbon Dioxide Production and on the Estimation of External Work from the Respiratory Metabolism —*J Hyg*, **21,** 4

HAMBLY, W. D., and MCSWINEY, B A. (1922): The U-tube Manometer Test with relation to Muscular Exercise —*Proc. Physiol. Soc.,* Oct 21, 1922

HAMBLY, W D, PEMBREY, M. S., and WARNER, E C. (1925): The Physical Fitness of Men assessed by various Methods.—*Guy's Hosp Rep*, Oct, 1925

HEWITT, E. M, and BEDALE, E M (1923) A Study of the Comparative Physiological Costs of Different Methods of Weight Carrying by Women —*Ann. Rep of the Chief Inspector of Factories for* 1922.

HILL, A. V. (1927): *Muscular Movement in Man.* New York.

HILL, A. V. (1927): *Living Machinery.* London.

HILL, A. V, LONG, C. N. H., and LUPTON, H (1924): Muscular Exercise, Lactic Acid and the Supply and Utilisation of Oxygen.—*Proc. Roy. Soc.*, B **96,** 438, **97,** 84; **97,** 155.

HILL, A. V., and LUPTON, H. (1923). Muscular Exercise, Lactic Acid, and the Supply and Utilisation of Oxygen.—*Quart. J. Med.*, **16,** 62.

HILL, L, VERNON, H. M., and HARGOOD-ASH, D. (1922): The Kata-Thermometer as a Measure of Ventilation —*Proc. Roy Soc.,* B. **93,** 198.

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LANGDON, J. N and YATES, E M (1928) · Transfer of Training in Manual Dexterity.—*Memoirs of Manchester Literary and Philosophical Society,* January.

LANGDON, J. N. and YATES, E. M, (1928): An Experimental Investigation into Transfer of Training in Skilled Performances —*Brit J. Psychol.*, **18,** 4.

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LUPTON, H. (1923): Exercise and Oxygen —*Med School Gaz.*, **2,** 3.

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NEWBOLD, E. M. (1923): Note on Dr Burnside's Paper on Errors of Observation.—*Biometrika*, **15,** 3 & 4.

PEAR, T. H (1927): Repetitive Work.—*Dictionary of Industrial Administration.*

PEAR, T. H. (1927): Work, Temperament and Fatigue.—*Rep. Internal. Ass. for Study of Relations and Conditions in Industry.* (Baveno), 1927.

PEAR, T. H. (1927): Recent Studies of Skilled Performance with reference to Transfer of Training.—*Nature,* 18th Jan.

PEAR, T. H., LANGDON, J. N. and YATES, E. M. (1928): The Nature of Manual Dexterity and its Relation to Vocational Training.—*Nature,* 12th May, 1928.

PEAR, T. H., LANGDON, J. N. and YATES, E. M. (1928): Transfer of Training and Transference.—*New Era,* June, 1928.

PEAR, T H. (1928) : *Fitness for Work,* London

PEAR, T H. (1928) : The Nature of Skill. (Presidential Address to the Psychology Section of the British Association, Glasgow) — *J. Ind Ind Psychol.*, **4,** 193, and Abstr. *Nature,* 8th Sept., 1928.

PEMBREY, M. S , and OTHERS (1922) . Tests for Physical Fitness —Part I — *Guy's Hospital Reports,* Oct , 1921 Part II — *Ibid* , Oct , 1922.

RUSHER, E. A (1922) : The Statistics of Industrial Morbidity in Great Britain — *J Roy Stat. Soc.*, **85**, 1.

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SMITH, MAY (1923) : The Laundry Trade —*Laundry Record,* **33,** 388

SMITH, MAY (1926) . Industrial Psychology — *Article in Enclyclopædia Britannica (XIIth Edition).*

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WILSON, D. R. (1921) : The Work of the Industrial Fatigue Research Board, and its Applications to Industry.—*J. Roy. Soc. Arts.*, **70,** 3660.

WILSON, D R. (1923) : On Some Recent Contributions to the Study of Industrial Fatigue.—*J Roy. Stat. Soc.*, **86**, 4.

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Report No. 58.

MEDICAL RESEARCH COUNCIL.

INDUSTRIAL
HEALTH RESEARCH BOARD

(Formerly The Industrial Fatigue Research Board).

A Study of Heating and Ventilation in Schools.

By H. M. VERNON and T. BEDFORD

(assisted by C. G. WARNER).

LONDON:
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PREFACE.

The artificial heating and ventilation of factories have already been the subject of two investigations under the Industrial Health Research Board, in which the physiological effects of different systems in actual use in factories have been compared.* Since the results of these were published, the Board have learned that several new methods, not yet applied in industrial establishments, have been installed in schools in different parts of the country, and they decided that their investigations should be extended so as to explore the special characteristics of these new methods and to determine how far they could usefully be adopted in factories. At the same time the opportunity was taken of making observations in open-air schools, and of investigating in some detail the regularity of attendance of the children at various types of schools.

---

* "A Physiological Study of Ventilation and Heating in Certain Factories," by H. M Vernon and T. Bedford (assisted by C. G. Warner), *Report No. 35*

"A Physiological Investigation of the Radiant Heating in Various Buildings," by H M. Vernon and M. D Vernon (assisted by I Lorrain-Smith), *Report No. 44.*

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A STUDY OF HEATING AND VENTILATION IN SCHOOLS.

BY

H. M. Vernon, M.D., and T. Bedford, Ph.D.,

ASSISTED BY

C. G. Warner, B.Sc.

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INTRODUCTION.

In the last few years several new methods have been adopted for the ventilation and heating of schools, offices, and other buildings, and it is important to determine how far, if at all, they are applicable to factories. It was considered desirable to ascertain whether their adoption in suitable cases would be likely to conduce to the health and comfort of industrial workers, and enable them to perform their manual work with the greatest possible efficiency. The observations to be described were, for the most part, carried out in various elementary schools where the novel forms of heating and ventilating were installed, as no factories were available for the purpose ; but we shall see that much of the evidence obtained can readily be applied to industry. At the same time the evidence is of direct value for the construction of schools, and if it does anything to promote the health of the school child, it must inevitably help to produce healthier and more vigorous industrial workers.

The novel forms of heating investigated were under-floor heating and panel heating, whilst the ventilation consisted of various degrees of open-air and semi-open-air ventilation.

Under-floor heating was adopted in Roman times, when the heat from the hypocaust was conducted under the floor, and sometimes in addition through hollow bricks built into the walls It has recently been employed in Liverpool Cathedral, the entire floor space of which consists of a double floor enclosing a series of shallow ducts, about 12 in. by 9 in. in cross section. These ducts form a closed system, through which warmed air is circulated by means of a fan. This installation has recently been tested by one of us in conjunction with M. D. Vernon, and is referred to in Report No. 46 of the Board (1928). In this report investigations on the panel system of heating by means of large radiating areas in the ceiling and walls are described The observations were chiefly made in large offices and other buildings, and they indicated that the system is very suitable for factories. The observations made on the panel system in the present investigation are a continuation of the previous series, and were designed to yield more extensive evidence of the physiological effects of the radiant heating.

METHODS OF INVESTIGATING THE PHYSIOLOGICAL EFFECTS OF VENTILATION AND HEATING.

In a previous investigation on the ventilation and heating of factories (1926), we showed that all the systems usually in vogue caused the temperature of the air at head level to be higher than at foot level, the difference sometimes amounting to 8° F. That is to say, they tended to keep the heads of the workers warm and their feet cool. The panel system, on the other hand, was found (1928) to keep the temperature of the air nearly uniform at all levels, whilst a system of under-floor heating might be expected to keep the feet distinctly warmer than the head, and might on that account induce a greater sensation of comfort. The actual effects produced can be ascertained only by making series of comparable observations under the various systems of heating. The three investigators were the subjects of this comparison, and they made numerous series of observations on themselves.

Physiological Tests.—The influence of the system of heating upon the surface temperature of the head, hands and feet was ascertained by means of a thermopile. The instrument used, a Moll thermopile, has already been described by one of us in detail (1928). It was connected with a Cambridge and Paul unipivot dead-beat galvanometer, and its readings were always standardised by exposing it to the radiation from a matt black tin before and after exposing it to the skin surface. This tin contained water at approximately the temperature of the air at head level. The mouth of the cone of the thermopile is 2·4 in. (6·0 cm.) in diameter, and it was held within a quarter of an inch of the surface when taking a skin temperature For head temperature, the forehead was thought to be a better position than the cheek, as it is flatter. The hand temperature was taken in two positions, (*a*) the palm, with the rim of the cone coming to within a quarter of an inch of the web of the fingers, and (*b*) the fingers (palmar side), again with the rim of the cone coming to within a quarter of an inch of the web. In small children the palm of one hand is not big enough to cover the whole of the area of the cone, so we got them to put the two hands together The foot temperature was taken, not on the sole as it is rather awkward to get at it, but on the upper surface of the foot, with the rim of the cone about a third of an inch from the web of the toes. The temperature was taken immediately after removal of the shoe and sock, which were replaced directly the measurement was completed.

The Moll thermopile is an exceedingly convenient and accurate instrument for making surface temperature observations, as the galvanometer attached to it reaches its maximum deflection in about seven seconds. The observed deflections were converted into temperatures on the basis of the calibrations made against a matt black surface (lamp black), and they are accurate only if the emissivity of the skin is the same as that of the lamp black. An attempt was made to compare the two in the following manner. The surface temperature of the palmar and dorsal surfaces of both hands was measured twice at a 10-minute interval by means of the thermopile. The palm of one hand and the back of the other hand were then painted with a suspension of lamp black in water, and in order to equalise the cooling effect of the wet paint, the other two hand surfaces were painted with water. After an interval of 20 minutes the surface temperatures were re-determined twice as before. The hands were washed, and after a further 20 minutes the temperature of the clean surfaces was again determined. The paint was then laid on the opposite hand surfaces to those first painted, and the temperature measured. Finally the washed hands were tested for a third time. As a mean of a number of observations it was found that the temperature of the blacked skin surfaces differed by less than 1 °F. from that of the unblacked.

Another proof that the thermopile method indicates the true skin temperature is afforded by comparing our results with those of Kunkel (1889). This investigator used a thermo-electric method for estimating skin temperatures which appears to be accurate, and at an air temperature of 68° he found the temperature of the forehead to vary from 93·4° to 93·9°. The skin temperature varies appreciably with the air temperature, and we ourselves observed the following forehead temperatures at various air temperatures (the means of 24 to 40 observations in each case).

Air Temperature.		*Forehead Temperature of Investigators.*				
		V.	*B.*	*W.*	*Mean.*	
In floor-heated room at 62·1	61·0°	93·3°	93 5°	93·7°	93·5	93·2°
In stove-heated room at 60·8		92·4	93·2	92·9	92·8	
In floor-heated room at 56·6	56·0°	92·3	92·4	92·8	92·5	92·1°
In stove-heated room at 55·5		91·1	91·8	92·2	91·7	

It will be seen that a rise in the air temperature from 56° to 61° increased the forehead temperature from 92·1° to 93·2°. At 68°, therefore, the forehead temperature would probably have been over 94°, or slightly higher than the value observed by Kunkel, but the difference is well within the limits of experimental error.

The temperatures recorded are somewhat higher than those found by Campbell, Hargood-Ash and Hill (1921), who used the direct method of rolling the thermometer bulb against the cheek, but agree well with the observations of Campbell and Angus (1928), who used the same method, and found that it gave results closely corresponding with the thermo-electric method.

Our other physiological tests consisted in the determination of the mouth temperature by clinical thermometer, and in a manual dexterity test, which is referred to later on.

Psychological Tests.—These consisted in noting down the sensation of air temperature and of air movement according to an agreed scale. The scale of marking adopted is that previously described (9), viz. :—

Sensation of Air Temperature.		*Sensation of Air Movement.*	
Much too warm	1	Very stagnant	1
Too warm	2	Stagnant	2
Comfortable	3	Medium	3
Too cold	4	Fresh	4
Much too cold	5	Very fresh	5

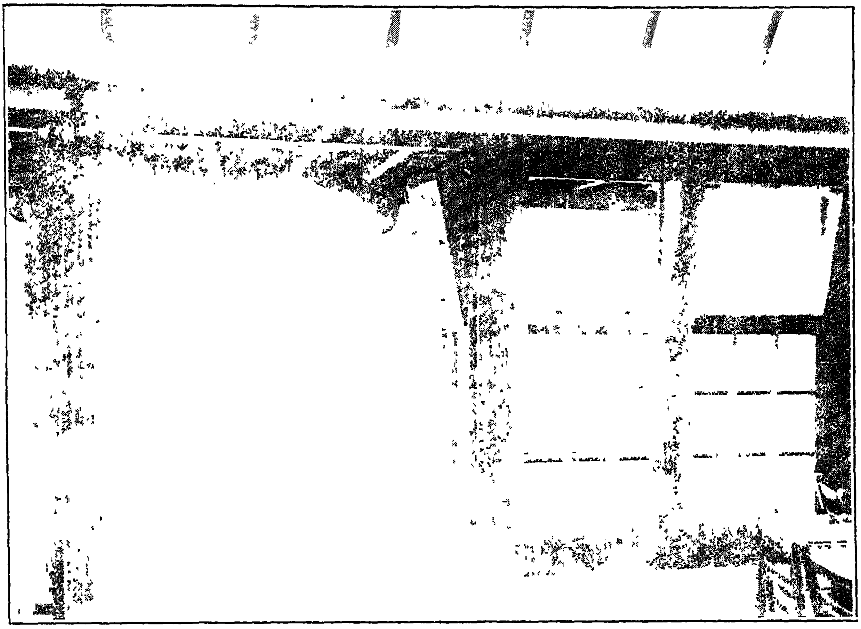

Fig. 1.—Class room with one pair of doors fastened back, and one window flap turned down

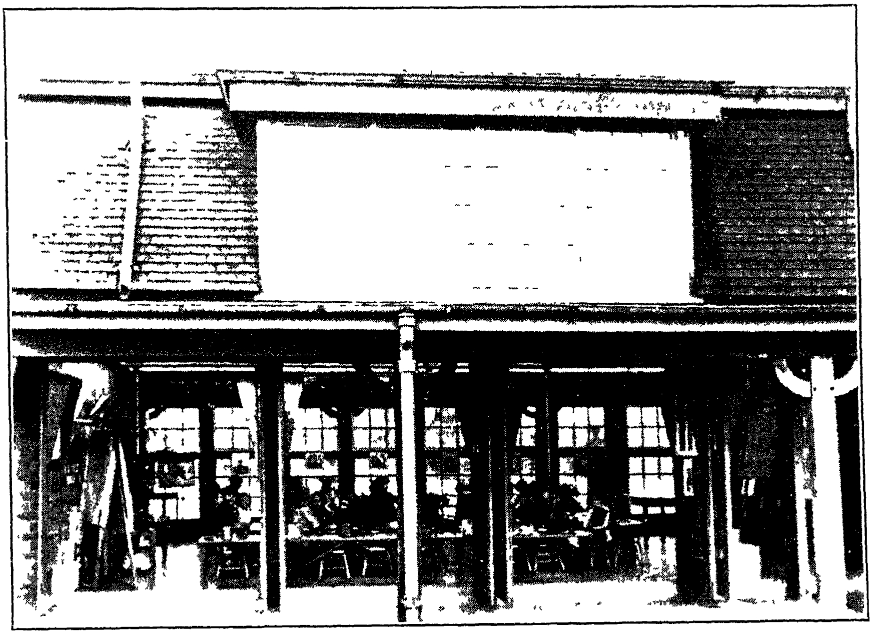

Fig 2—Class room (with N. and S windows) showing all the doors fastened back in pairs

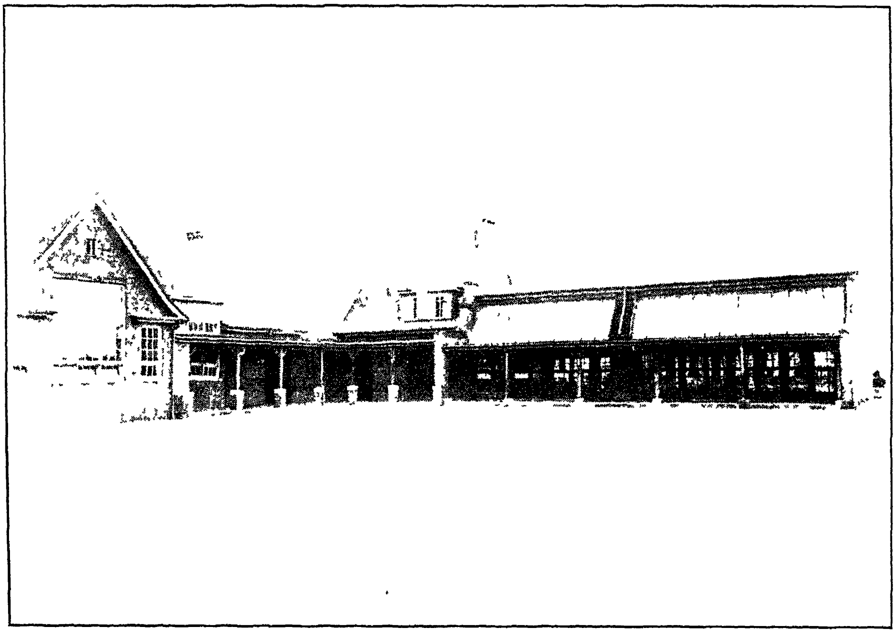

Fig. 3.—School with floor-heated class rooms on right side, and ordinary type of class room on left side

The sensations of air temperature and of air movement for the most part ran parallel, e.g., too warm air usually felt stagnant, and too cold air usually felt fresh, but they did not always correspond, and each investigator noted down each of the two sensations independently. He endeavoured to assess his sensations in fractions of units, and not merely in the whole numbers quoted. The degree of correspondence between the reactions of the investigators is illustrated later on

COMPARISON OF EFFECTS PRODUCED BY UNDER-FLOOR HEATING AND BY STOVE HEATING.

As far as we are aware, under-floor heating has hitherto—with the exception of the cathedral previously mentioned—been adopted only in a few elementary schools. These schools have recently been erected in Derbyshire by the County Council, to the design of their architect, Mr. G. H. Widdows (1921). In them the heating is effected by means of low-pressure hot water. The hot-water pipes, 2 in in diameter, are supported 2 in. above the level of an under-floor of concrete, which is 6 in. in thickness. Three inches above the pipes comes the actual floor, consisting of slabs of concrete, 7/8 in. thick and 27 in. wide. Each slab is strengthened by three ribs underneath, and its edges rest on porous bricks. On the top is a layer of composition "granwood" tiles, 5/8 in. thick, embedded in cement. The under-floor pipes, which are 16 in. apart, are supplied from a 3½ in. pipe which runs horizontally along one or two walls of each class room, at a height of 7¼ ft. above the floor (*cf.* Fig. 1, where it is seen just below the skylight). They maintain the floor at a temperature of 63° to 76°.

The class rooms are usually 24 ft. in the east to west direction, 21½ ft. north to south, and 13½ ft. in height. The north and south sides consist of a single glazed door together with three pairs of glazed swing doors which can be fastened back against one another so as to throw the whole class room open to the air (*cf.* Figs. 1 and 2). Each door is 6 ft. 7 in. in height and 34 in. in width. In the upper part it has a hopper 30 in. wide and 26½ in. high, with wooden gusset pieces at the sides. When open, the hopper gives a ventilation area of 30 in. by 4½ in., but the whole flap can be turned down (*cf.* Fig. 1), and it then gives a ventilation area of 26½ in. by 25 in. A point upon which Mr. Widdows lays stress is the construction of the outer opening of the hopper at a level slightly below that of the inner opening, whereby the currents of cold air entering the room are diverted upwards, and prevented from blowing directly on to the children.

Outside each of the north and south sides of the class rooms is a broad veranda, under which the children often sit in warm weather. The south veranda prevents all but the low-angle winter sunlight from entering the rooms, and as there are no south windows above the veranda in the most recently designed schools, it follows that in them practically no sunlight reaches the children. In the class rooms first designed there was a large south-light window (*cf.* Fig. 2), and this feature could be re-introduced if thought desirable. The window has curtains, which can be drawn if the sunlight is considered to be excessive. The present system of lighting consists of a huge north-light window, 6 ft. by 23 ft., running nearly the whole length of the room. Two of these windows are shown on the right side of Fig 3, whilst the left side shows windows of the earlier type, consisting of swivels at the top and hoppers at the bottom. The cold air which falls from the big north-light windows is tempered by the hot air rising from the hot water pipe running just below it.

A preliminary account of these class rooms, and of the effects of their atmospheric conditions on the investigators and on the children was given by one of us (Vernon) in 1928.

The authorities kindly placed one of the floor-heated rooms at our disposal, and we made three series of observations in it. We so controlled the ventilation that the dry kata cooling power averaged 6·8, 8·3 and 10·1 in the three series For purposes of comparison we made series of observations in a stove-heated room at a cooling power of 6·8 and 8·3, the observations at a cooling power of 10·1 being omitted. The stove room, 18 ft. by 15½ ft. in area, and 10¼ ft. in height, was heated by an anthracite stove, but all direct radiation from this stove to the subjects of experiment and to the thermometer recording the air temperature was prevented by the interposition of a wooden screen. The air temperature was therefore maintained by convection currents from the stove. The subjects sat at a table 7 ft. from it, and in order that they might experience similar atmospheric conditions, they changed places every six or seven minutes (i.e., when they took their turn at various tests). The room was ventilated by two large sash windows, a door being sometimes kept partly open in addition, in order to get the requisite cooling power.

The air temperature was measured at distances of 6 in., 4 ft. 9 in. and 7 ft. 3 in. above floor level, the stand previously described (10) being used for supporting the instruments. The floor temperature was determined at two places by the plasticene method previously described (10), and a mean taken. In three series out of the five our experiments lasted three hours, during which time the tests and observations were repeated at 20-minute intervals. In the remaining two series they lasted 2 hours 20 minutes. Each experiment was made on four occasions, those made at a cooling power of 8·3 and 10·1 being in the morning, and those at a cooling power of 6·8 in the afternoon. The experiments in the floor-heated room were made in January, 1928, when the outside air temperature averaged 40° in the morning and 42° in the afternoon. Those in the stove-heated room were made a month later, when the outside temperature averaged 42° in the morning and 47° in the afternoon.

The mean atmospheric temperatures observed in the two rooms are shown in Fig. 4. When the cooling power of the air was 6·8 (the mean of the observations at 4 ft. 9 in. and 6 in. levels), the floor temperature in the floor-heated room averaged 76·0°, and was 19° warmer than that of the stove-heated room. The air temperature 6 in. above the floor was 6° warmer than in the stove-heated room, but the air at head level was only 1° warmer. These higher temperatures were neutralised by a greater degree of air movement, the velocity in the floor-heated room being nearly double that experienced in the stove-heated room. It would have been more satisfactory if the temperatures and air velocities in the two rooms could have been kept at approximately the same figure, but this we were unable to achieve, for it happened that when the stove-room observations were made the outside air was extremely calm, whilst it was rather windy during the experiments in the floor-heated room. Also the temperature of the floor in the floor-heated room was not within our control. However, we were able to regulate conditions so as to get exactly the same average cooling power in the corresponding sets of observations in the two rooms. Also it will be seen from Figs. 5 and 6 that the cooling power was maintained at a fairly steady level throughout the experiments.

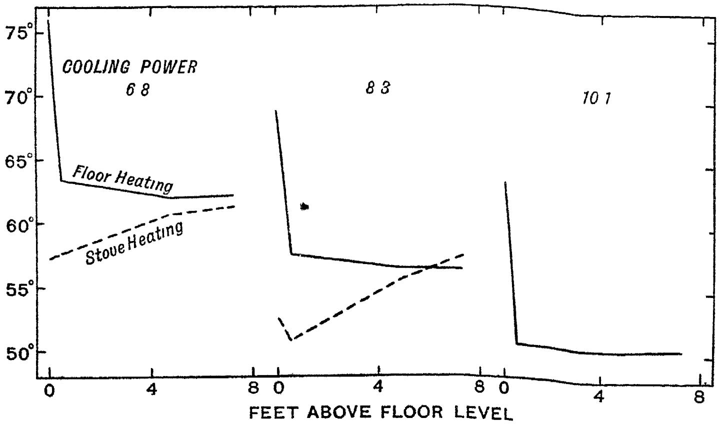

Fig 4.—Temperature gradients in under-floor-heated and stove-heated rooms.

The effects of the atmospheric conditions on the mean surface temperatures of the three subjects are shown in Fig. 5. Considering first the observations made at a cooling power of 8·3, it will be seen that the forehead temperature remained steady throughout the three hours, though it was nearly 1° lower in the stove room than in the floor-heated room. The other surface temperatures fell fairly steadily throughout the three hours. The finger temperatures (the records of which are omitted for the first hour for the sake of clarity) corresponded moderately well in the two rooms and so did the palm temperatures, but the foot temperatures were about 5° lower in the stove-heated room than in the floor-heated one. This difference of temperature was the direct effect of the warm floor, and it is interesting to determine what influence this warming of the feet had upon the general sensation of comfort and warmth experienced by the subjects.

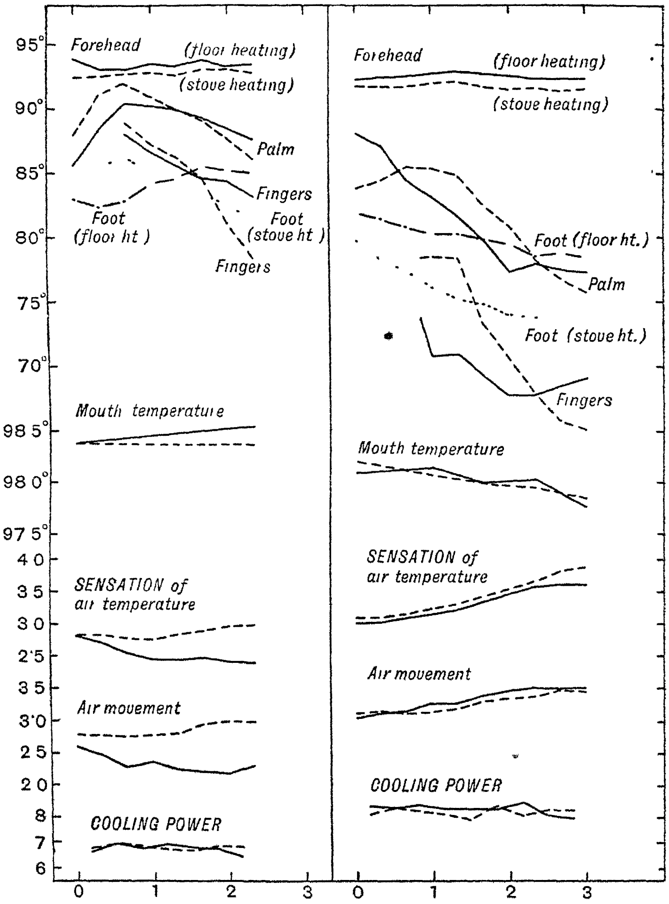

Fig. 5.—Means of observations on three subjects in floor-heated and stove-heated rooms at cooling powers of 6·8 and 8·3.

At the beginning of the session the mean sensation of air temperature experienced was 3·0 in the floor-heated room and 3·1 in the stove room, i.e., it was approximately " comfortable " in each instance. After three hours it had changed to 3·6 in the floor-heated room and to 3·9 in the stove room, i.e., it had nearly reached a " too cold " sensation in the latter instance, but was distinctly short of this sensation in the former instance.

TABLE I.—THE INFLUENCE OF FLOOR HEATING AND STOVE HEATING ON SKIN TEMPERATURES.

Measurement.	Floor heating.	Stove heating.	Difference.		Floor heating.	Stove heating	Difference.		Mean of both sets of data at cooling power of			
									6·8	8·3	Difference.	
Cooling power	6·8	6·8	0·0		8·3	8·3	0·0		6·8	8·3	+ 1·5	
Mean air temperature (dry bulb) ..	62·8°	59·3°	− 3·5°		57·2°	53·2°	− 4·0°		61·0°	55·2°	− 5·8°	
Relative humidity (% saturation)..	52	62	+10		57	73	+16		57	65	+ 8	
Mean air velocity (ft. per min.) ..	30	18	−12		35	21	−14		24	28	+ 4	
Final temperature of forehead ..	93 5°	93·0°	− 0·5	−2·2°	92·3°	91·5°	− 0·8	−2·6°	93·2°	91·9°	− 1·3	−8·5°
,, ,, ,, palm ..	88·1	86·9	− 1·2		77·4	76·3	− 1·1		87·5	76·8	−10·7	
,, ,, ,, fingers ..	83·8	79·8	− 4·0		68·9	65·4	− 3·5		81·8	67·2	−14·6	
,, ,, ,, foot	85·1	82·1	− 3·0		78·6	73·4	− 5·2		83·6	76·0	− 7·6	
Final sensation of air temperature	2·4	3·0	+ 0·6	+0·65	3·6	3·9	+ 0·3	+0·15	2·7	3·75	+ 1·05	+0·95
,, ,, ,, air movement..	2·3	3·0	+ 0·7		3·5	3·5	0·0		2·65	3·5	+ 0·85	

This result, coupled with the fact that the forehead temperature was lower in the stove room and the final hand temperatures were likewise lower, suggests that floor heating did have a genuine effect, though it was only a small one.

The observations made at a cooling power of 6·8 show more marked differences in their effects upon the sensations, though the skin temperatures were rather less influenced. The ultimate skin temperatures observed (the means of the last two observations being taken, in order to reduce chance error) are recorded in Table I, and it will be seen that the skin temperature was always lower in the stove room than in the floor-heated room, the mean difference for forehead, palm, fingers and foot being 2·2°. In air at a cooling power of 8·3 the mean difference of skin temperature was 2·6°. The sensation of air temperature experienced in the two rooms corresponded to the differences of skin temperature, for it averaged 3·0 (corresponding to "comfortable") in the stove room, whilst it was 2·4 (or more than half way towards "too warm") in the floor-heated room. The sensation of air movement in the floor-heated room, as compared with that in the stove room, was even smaller, in spite of the considerably greater air velocity.

There can therefore be no doubt that at equal cooling powers the air in the floor-heated room felt warmer and less in motion than the air in the stove room. It is of interest to determine, so far as is possible, what this increase of warmth amounted to in terms of air temperature. On the right side of Table I we have averaged the two series of observations made at a cooling power of 6·8, and also those at a cooling power of 8·3, and we see that the air temperature at the higher cooling power was 5·8° less than at the lower cooling power. The air velocity was slightly greater, however, and if we make a correction for this it appears that at equal air velocities the air temperature would have been 7° lower when the cooling power was 8·3. We see from the table that the mean skin temperature was 8·5° lower when the cooling power was 8·3, and as the mean skin temperature was $\frac{2{\cdot}2 + 2{\cdot}6}{2} = 2{\cdot}4^\circ$ lower in the stove room than in the floor-heated room, it follows that :—

Air temp. in stove room felt $7 \times \frac{2{\cdot}4}{8{\cdot}5} = 2{\cdot}0^\circ$ cooler than in floor-heated room.

Of course this estimate is only a rough one, but it is substantial enough to be significant. We can get another measure of the temperature equivalent from the sensation data, for we see that, on an average, the sensations of air temperature and air movement were ·95 greater in air at a cooling power of 8·3 than in air at a cooling power of 6·8. The sensations in the stove room were, on an average, $\frac{\cdot 65 + \cdot 15}{2} = \cdot 40$ greater than in the floor-heated room ; hence it follows that :—

Air temp. in stove room felt $7 \times \frac{\cdot 40}{\cdot 95} = 2{\cdot}9°$ cooler than that in floor-heated room.

This estimate is less reliable than the last one, but it roughly corresponds with it, and we may say that at equal cooling powers the stove room felt about 2·5° cooler than the floor-heated room. Though this temperature difference is fairly substantial, it is not to be argued that children sitting in an open-air floor-heated room at (say) 57·5° would feel as warm as other children sitting in ordinary rooms at 60°, for the open air system usually induces a greater air velocity than ordinary rooms do, and this may neutralise the extra heating effect of the under-floor system. Moreover, the results of a comparison of a floor-heated room with a stove room where there was a somewhat considerable temperature gradient, do not necessarily hold for other rooms which are so heated as to give very little temperature gradient.

Any extra heating effect the under-floor system does possess may be due largely to the extra heat received directly by conduction from the warm floor through the soles of the feet, or more accurately speaking, to the reduction in the loss of heat from the feet in the floor-heated room as contrasted with the loss of heat experienced in the stove-heated room.

The results of the observations made in the floor-heated room when maintained at a cooling power of 10·1 are recorded on the right side of Fig. 6, and the corresponding observations made at cooling powers of 8·3 and 6·8 are given for comparison. It will be seen that at the high cooling power mentioned, when the air temperature averaged 50·4° and the air velocity 38 ft. per min., the mouth temperature fell rapidly, and at the end of the morning it was only 97·1°, or 1·1° lower than at the start. The forehead temperature fell 2°, whilst that of palm, fingers and foot fell 13°, 18° and 7° respectively. The sensation of air temperature was 3·4 at the start, or nearly half way towards " too cold ", and ended at 4·9, or very nearly " much too cold ", whilst the sensation of air movement started at 3·8, and ended at 4·7.

It is evident that in estimating the effect of atmospheric conditions the full response takes three hours or more to show itself in full strength. In the previous investigation on the effects of radiant heating (10) the subjects sat only half-an-hour in various positions, and then recorded their sensations, so they could not have experienced a maximum effect. However, even half-an-hour's exposure is sufficient to give an indication of the sensation which will ultimately be experienced, as is shown by comparing the sensations experienced in the present observations after half-an-hour and after 3 hours (or 2 hours 20 minutes). The observations at cooling powers of 6·8 and 8·3 are the means of the series made in both rooms.

Cooling Power of Air.	*Sensation of Air Temperature.*		*Sensation of Air Movement.*	
	After ½ hour.	*After 3 hours.*	*After ½ hour.*	*After 3 hours.*
6·8	2·7	2·7	2·6	2·6
8·3	3·1	3·7	3·1	3·5
10·1	3·6	4·9	3·4	4·7

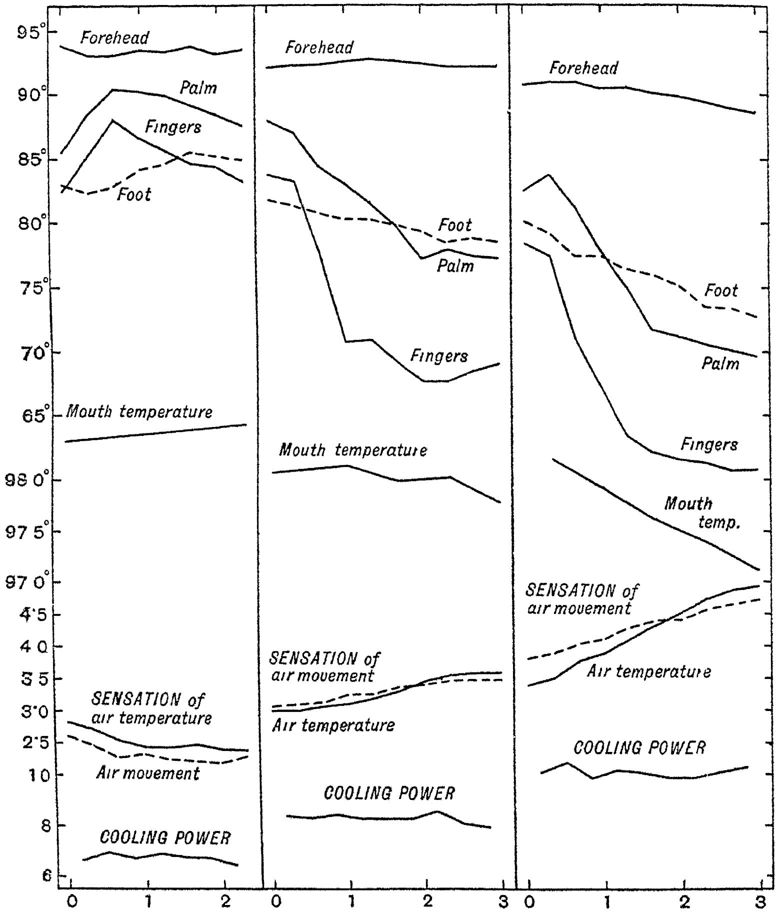

Fig. 6.—Observations in floor-heated room at cooling powers of 6·8, 8·3 and 10·1.

We see that in each case the difference in the sensation of air temperature from that of comfort (=3·0) showed itself in half-an-hour, though this difference was much accentuated in the three hours.

All the results so far described are the averages observed for the three subjects of experiment, but there were considerable individual differences. For instance, in air at a cooling power of 8·3 the final foot temperatures in the three subjects ranged from 76° to 85° in the floor-heated room, and from 72° to 80° in the stove room. The palm temperatures were more steady, as they ranged only from 75° to 80° in the floor-heated room and from 74° to 78° in the stove room. Different individuals possess personal peculiarities of surface temperature which they tend to maintain at all times. For instance, after three hours' exposure to air at a cooling power of 10·1, one subject had a foot temperature which ranged from 81° to 77° in the four series of observations, whilst another had a temperature which was always some 10° lower, as it ranged from 70° to 68°. On the other hand the palm temperatures were very similar, as they ranged from 70° to 68° in the one subject and from 71° to 68° in the other. In contradistinction to the variations shown in the temperature of the hands and feet, that of the face was very steady. For instance, in the four experiments made in air at a cooling power of 10·1, the final forehead temperature of two subjects varied only from 89° to 90°, and that of the third subject from 86° to 88°.

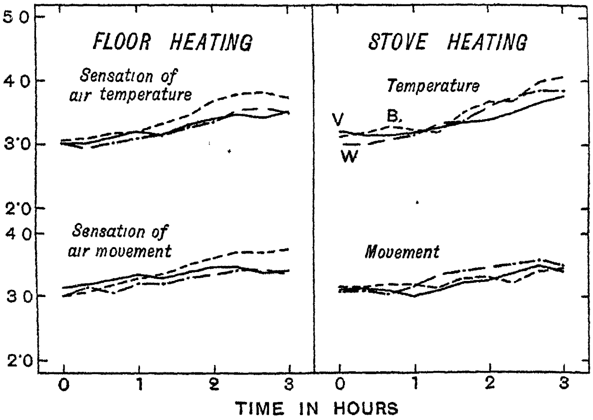

Fig. 7.—Sensations of air temperature and air movement experienced by the three subjects during three hours at a cooling power of 8·3.

The three subjects showed a much closer correspondence in their sensations of air temperature and air movement than in their hand and foot temperatures. In Fig. 7 are recorded the mean sensations experienced by each subject during the three hours' session in the two rooms when the cooling power was at 8·3. It will be seen that in no instance did they differ by more than 0·4 unit, so it follows that the mean sensations recorded in Figs. 5 and 6 can be accepted with considerable assurance.

COMPARISON OF EFFECTS PRODUCED BY PANEL HEATING AND BY PROTECTED GAS-FIRE HEATING.

Similar series of observations to those mentioned above were made at another school, near London, where the heating was effected by means of exposed cast iron panels in the ceiling.

There were five class rooms, varying somewhat in size, the room used by us being 21 ft. from N. to S. and 19½ ft. from E. to W. The room was 12 ft. in height, and just below the ceiling were fastened four iron panels, each 2½ ft. by 8¼ ft. in area, so the total heating surface, including the pipe connections, was approximately 84 sq. ft. The panels ran from E. to W., and their outer edge was within 1 ft of the N. and S. edges of the ceiling (*cf* Fig. 8). The glazed doors on the N. and S. sides of the class rooms could be fastened back so as to throw the rooms completely open to the air, whilst the windows above them (each 2 ft. square) were on swivels During cold winter weather these windows alone were used for ventilation, the doors being kept shut. In addition to the ceiling-panel heating, a 3½ in. hot water supply pipe ran on each side of the room just below the level of the swivel windows, whilst a smaller pipe ran beneath the flooring near the doors, and raised its temperature about 7°. On the single occasion on which we tested the surface temperature of the supply pipe we found it to be 147°, whilst that of the ceiling panels averaged 112°.

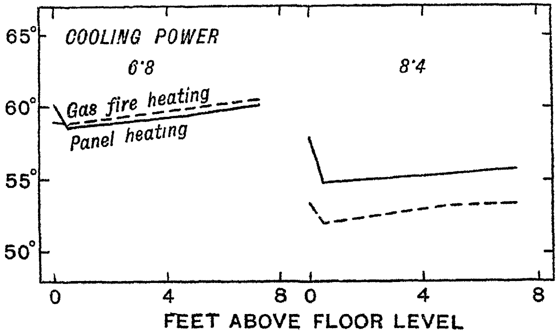

Fig. 9.—Temperature gradients in rooms with panel heating and (protected) gas-fire heating.

The school room observations were made in December, 1928, when the outside temperature averaged 45°, and a series of control observations was made shortly before them, at a time when the outside temperature averaged 48°. They were made by two investigators only (H.M.V. and C.G.W.), in a room 18 ft. by 15 ft. in area, and heated by a gas fire. Direct radiation from the fire to the subjects was prevented by the interposition of a wooden screen, but it might be thought that some of the radiant heat from the fire, after striking the ceiling and walls, would be reflected on to the subjects. Determination of the mean radiant temperature of the walls, etc., of the room (by a method to be described on a later occasion) showed that its temperature was only 0·8° above that of the air, so for all practical purposes the system of heating of this control room may be regarded as one of convection air heating.

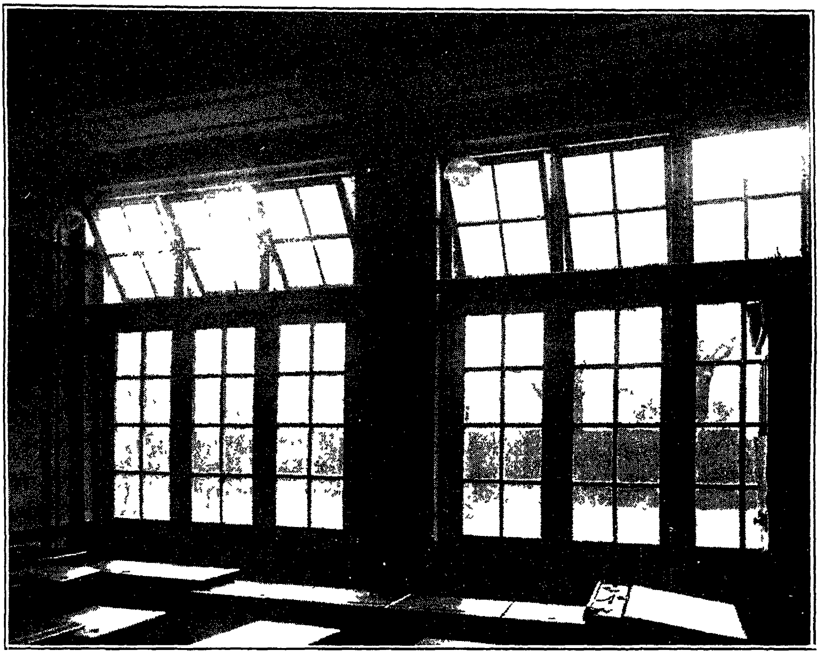

Fig 8 —Class room with ceiling panel heating and glazed swing doors

The mean temperature gradients observed in the two rooms are plotted in Fig. 9, and it will be seen that they indicate a fairly even distribution of temperature. The floor temperature in the panel room at a cooling power of 8·4 was 3·2° higher than that of the air immediately above it, owing to the radiation from the panels, but at a cooling power of 6·8 the excess of floor temperature was only 1·5°.

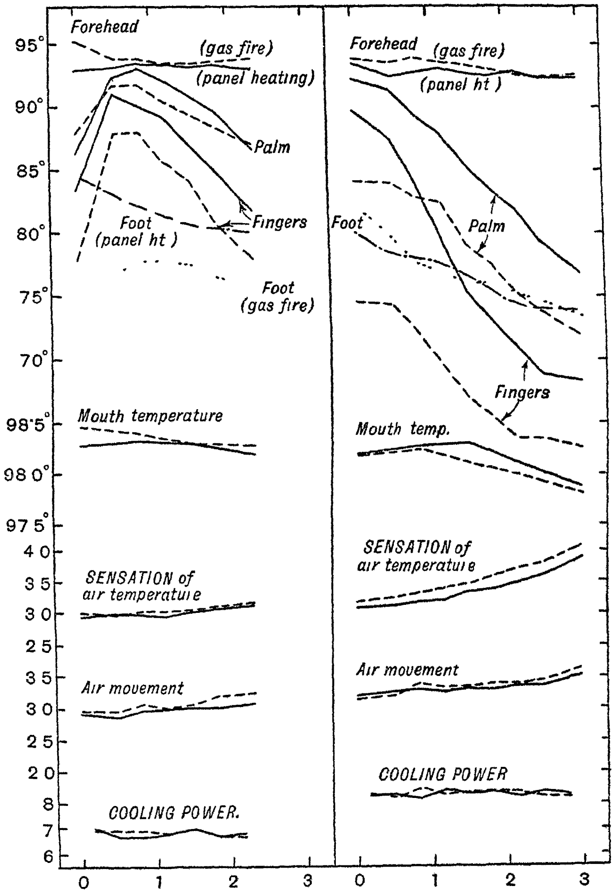

Fig. 10.—Means of observations on two subjects in panel-heated and gas-fire heated rooms at cooling powers of 6·8 and 8·4.

The mean results of the four series of observations made at each cooling power on the two investigators are plotted in Fig. 10. It will be seen that the correspondence is fairly good at a cooling power of 6·8, but not so close at one of 8·4. The means of the two final observations in each series are recorded in Table II, and it will be seen that at a cooling power of 6·8, when the mean air temperatures and air velocities were almost exactly

TABLE II.—THE INFLUENCE OF PANEL HEATING AND (PROTECTED) GAS-FIRE HEATING ON SKIN TEMPERATURES.

Measurement.	Panel heating.	Gas-fire heating.	Difference.		Panel heating.	Gas-fire heating.	Difference.		Mean of both sets of data at cooling power of			
									6·8	8·4	Difference.	
Cooling power	6·8	6·8	0·0		8·4	8·4	0·0		6·8	8·4	+ 1·6	
Mean air temperature (dry bulb) ..	59·0°	59·3°	+ 0·3°		55·0°	52·6°	– 2·4°		59·2°	53·8°	– 5·4°	
Relative humidity (% saturation) ..	63	76	+13		65	68	+ 3		69	66	– 3	
Mean air velocity (ft. per min.) ..	18	18	0		28	20	– 8		18	24	+ 6	
Final temperature of forehead ..	93·4°	93·7°	+ 0·3	–0·1°	92·4°	92·4°	0·0	–2·5°	93·5°	92·4°	– 1·1	–8·4°
,, ,, ,, palm ..	88·7	88·1	– 0·6		78·5	73·2	– 5·3		88·4	75·8	–12·6	
,, ,, ,, fingers ..	84·0	79·9	– 4·1		68·6	63·5	– 5·1		81·9	66·1	–15·8	
,, ,, ,, foot	76·3	80·3	+ 4·0		74·0	74·3	+ 0·3		78·3	74·1	– 4·2	
Final sensation of air temperature ..	3·1	3·1	0·0	+0·10	3·7	3·9	+ 0·2	+0·15	3·1	3·8	+ 0·7	+0·55
,, ,, ,, air movement ..	3·0	3·2	+ 0·2		3·4	3·5	+ 0·1		3·1	3·5	+ 0·4	

the same in the two rooms, the final forehead and palm temperatures were likewise almost the same. However, the final finger temperature was 4° lower in the gas-fire room, whilst the final foot temperature was 4° higher, so the mean of all four temperatures (forehead, palm, fingers and foot) was practically the same. The sensation of air temperature was likewise the same in the two rooms, whilst that of air movement was slightly greater in the gas-fire room. In the observations made at a cooling power of 8·4 the gas-fire room proved slightly cooler than the panel room, for the palm and fingers were 5° cooler, whilst the sensations of air temperature and movement were 0·1 to 0·2 unit greater.

In order to obtain a numerical measure of the differences of effect produced by the two rooms in terms of air temperature, we have, as before, averaged the two sets of observations at a cooling power of 6·8, and likewise those at 8·4. We see from the table that the rise of cooling power from 6·8 to 8·4 corresponded with a fall of 5·4° in air temperature and an increase of 5 ft. per minute in its velocity, but at equal air velocities the fall of air temperature would have been 7°. The mean skin temperature was 8·4° less at the higher cooling power, whilst the mean skin temperature in the gas-fire room was $\frac{0{\cdot}1+2{\cdot}5}{2} = 1{\cdot}3^\circ$ less than that observed in the panel-heated room. Hence it follows that :—

Air temp. in gas-fire room felt $7 \times \frac{1{\cdot}3}{8{\cdot}4} = 1{\cdot}1^\circ$ cooler than in panel room.

Again, we see that the mean sensations of air temperature and air movement were ·55 unit higher at a cooling power of 8·4 than at one of 6·8, whilst they were $\frac{{\cdot}10 + {\cdot}15}{2} = {\cdot}12$ unit higher in the gas-fire room than in the panel-heated room. Hence it follows that :—

Air temp. in gas-fire room felt $7 \times \frac{{\cdot}12}{{\cdot}55} = 1{\cdot}5^\circ$ cooler than in panel room.

These two fairly consistent results agree in showing that the protected gas-fire room felt rather more than 1° cooler than the panel-heated room. In a previous investigation (10) we found that rooms heated by an anthracite stove and by hot-water radiators felt 0·7° cooler than those heated by wall panels and ceiling panels, but these ceiling and wall panels were concealed, and were at a lower temperature than the exposed ceiling panels tested on the present occasion. We may therefore conclude that the radiation from hot-water-fed panels causes an extra heating effect on the individuals subjected to it corresponding to an increase of about 1° F. in air temperature. As has been

TABLE III.—COMPARISON OF CONVECTION-HEATED ROOMS WITH FLOOR-HEATED AND PANEL-HEATED ROOMS.

Measurement.	Convection heating.			Floor heating.	Difference from convection		Panel heating	Difference from convection.	
	Stove.	Protected gas fire.	Mean.						
Cooling power	7·55	7·6	7·57	7·55	0·0		7·6	0·0	
Mean air temperature (dry bulb) ..	56·2°	56·0°	56·1°	60·0°	+ 3·9°		57·0°	+ 0·9°	
Mean air velocity (ft. per min) ..	19	19	19	33	+14		23	+ 4	
Final temperature of forehead ..	92·3°	93·0°	92·7°	92·9°	+ 0·2	+2·6°	92·9°	+ 0·2	+1·1°
,, ,, ,, palm ..	81·6	80·7	81·1	82·7	+ 1·6		83 6	+ 2 5	
,, ,, ,, fingers ..	72·6	71·5	72·1	76·4	+ 4·3		76·3	+ 4·2	
,, ,, ,, foot ..	77·8	77·3	77·6	81·9	+ 4·3		75·2	− 2 4	
Final sensation of air temperature	3·45	3·5	3·48	3·0	−0·48	−0·44	3 4	−0·08	−0·09
,, ,, ,, air movement	3·25	3·35	3·3	2·9	−0·4		3·2	−0·10	

pointed out in the previous report, these low temperature radiation systems of heating have the further advantage of inducing a very even distribution of air temperature, together with a floor temperature which is about 3° higher than that of the air above it.

A comparison of the control observations made on the three investigators in the stove-heated room and, nine months later, on the two investigators in the protected gas-fire room, shows a very close correspondence. The results obtained in each instance at the two cooling powers have been averaged in Table III, and we see that none of the four skin temperatures differed by more than a degree, while the sensations did not differ by more than 0·1 unit. If we take a mean of the two sets of control data and regard them as the effect of convection heating, we find, by comparison, that the means of the observations (at cooling powers of 6·8 and 8·3) in the floor-heated room show an excess of 2·6° in skin temperature, whilst the sensations show a mean defect of 0·44 unit (i.e., the air felt comfortably warm and of medium velocity instead of nearly half way towards " too cold ", and a third of the way towards " too fresh "). In the panel-heated room, on the other hand, the excess of skin temperature was only 1·1°, and the defect of sensation, 0·09 unit.

MANUAL DEXTERITY IN RELATION TO HAND TEMPERATURE.

In considering the suitability of any systems of ventilation and heating, attention should be paid to the effect they may have on the manual dexterity of the individuals subjected to them. This question is particularly important in so far as it relates to industrial workers, but it is desirable that clerical workers and school children should not have their fingers cooled to such an extent that they lose some of their speed and skill in writing, drawing, knitting, etc. In order to ascertain the influence of hand temperature on manual dexterity, we performed a manual dexterity test at 20-minute intervals in all of our experiments in the floor-heated room and the stove room. The test employed was an imitation of an industrial process, namely, the assembly of bicycle chains. Two bicycle chain " combinations " were fixed by screws on a board at the correct distance apart, and in front of these combinations were four small trays, two of which contained 40 steel " studs," whilst on the right side of the combinations was a pile of 40 links. The test consisted in (*a*) picking up a stud with each hand and (*b*) inserting them into the holes of the two combinations which had to be connected together by means of links ; (*c*) picking up a link from the pile by means of the right hand and (*d*) balancing it on the top of the studs by means of the fingers and thumbs of both hands. All of these four stages were an exact reproduction of what is done in the genuine operation. Instead of following it up with movements of the feet against levers, as the operatives had to do, we merely took off the link and put it in another pile, and put back the two studs into the other trays. In each test we assembled and dis-assembled 40 links successively.

The dependence of the test on manual dexterity was shown by the great differences in the time taken by the three investigators after they had attained a fairly steady rate, the result of practice. It averaged 4·6, 3·8 and 3·0 minutes respectively. In order to render all the results comparable, and independent either of the differences of dexterity possessed by the individual subjects or of their degree of practice, the series of nine (or seven) determinations made at each session was treated as a unit containing its own standard. The time taken in the first four determinations, when the fingers had not yet cooled very much, was found to be fairly steady, so it was averaged and regarded as a standard, against which the times taken in the individual determinations were calculated as percentages.

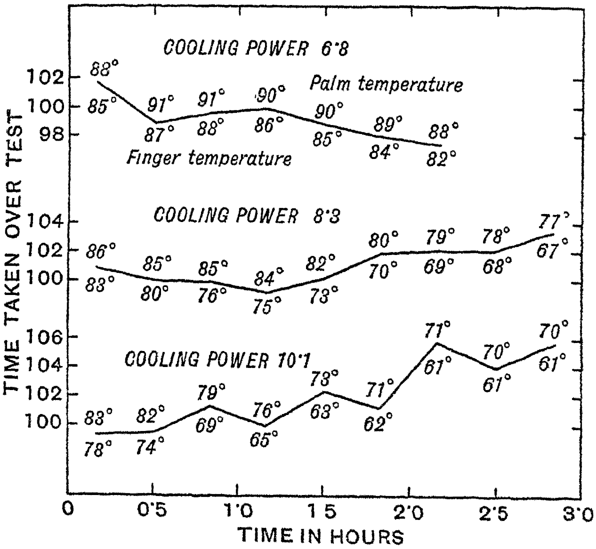

Fig. 11.—Time taken by investigators over manual dexterity test in relation to cooling power of air and temperature of hands.

The means of the observations on dexterity in relation to hand temperature are recorded in Fig. 11. The temperatures marked above each curve are the mean palm temperatures, and those below them are the finger temperatures. The observations made in the two rooms are combined, and it will be seen that in air at a cooling power of 6·8 the time taken over the test was at a maximum at the start (viz., 101·7), whilst it fell gradually during the course of the next two hours, the final value being 97·4. This increase of speed was the result of practice during the course of the session, and it occurred in spite of the fact that there was a slight fall in the palm and finger temperature. In the observations made at a cooling power of 8·3 the initial time taken was 100·9, and it fell gradually for the first hour, in spite of the finger temperature falling from 83° to 75°. With further fall of finger temperature it gradually rose, till at the end of three hours it was 103·5. In the observations made at a cooling power of 10·1 the fingers cooled so rapidly that manual dexterity deteriorated right from the start, and after three hours the time taken over the test averaged 105·7. This figure does not correctly represent the loss of speed, as it makes no allowance for the increase of manual dexterity which ensues with practice under suitable atmospheric conditions. An approximate allowance for this may be made by taking the observations in air at a cooling power of 6·8 as a standard. The observations made at this cooling power lasted 40 minutes less than those at the other cooling powers, and judging from the general trend of the curve, the improvement of speed would have continued steadily during this period. It can therefore be calculated that the ultimate test time would have been 96·0, so we find :—

In air at c.p. of 6·8 test time fell from 101·7 to 96·0 = 5·7
In air at c.p. of 10·1 test time increased from 99·3 to 105·7 = 6·4

Hence the effect of the increased cooling power was roughly 5·7 + 6·4 = 12·1, so the cooling of the fingers reduced manual dexterity by about 12 per cent.

The observations made at the different cooling powers are consistent in showing that the loss of manual dexterity began at about the same hand temperature Thus at a cooling power of 8·3 the speed began to decrease when the palm temperature fell below 84°, whilst at a cooling power of 10·1 the critical temperature was 82°. No doubt this critical temperature varies a great deal in different subjects, for it averaged 88°, 76° and 84° respectively in subjects V., B., and W. We shall see that the palm temperature of the majority of school children tested fell considerably below our limit, and it might be thought children would be less affected by cold hands than adults. In order to test this surmise, we made a series of observations on three elementary school boys, aged 13½, in Dec.—Jan., 1928–29.

The boys in question were experimented on every morning from 9 a.m. to 12 noon for 10 days Every 20 minutes they performed the manual dexterity test above mentioned (assembling 30 links instead of 40), and they also did three four-figure multiplication sums. For the rest of the time they sat quietly round a table, reading, etc., whilst they had a break from 10·40 to 11·0 a.m., and ran about outside. In order to induce them to do their best throughout, they were paid a fixed amount each day, together with a bonus for each day on which they beat their previous day's score. As they were improving fairly rapidly throughout the test period, they almost always earned their bonus. The first day was used for practice only, and on the remaining nine days the tests were, with one exception, performed alternately in a moderately warm room and a cool room, under the following atmospheric conditions (means at 4 ft. 9 inches and 6 inches levels) :—

At a c.p. of 7·0 (= 56·5° and 14 ft. per min.) on days 1, 4, 6 and 8

At a c.p. of 9·1 (= 47·5° and 16 ft. per min) on days 2, 3, 5, 7 and 9.

No tests were performed on Sunday, which came between the third and fourth days of experiment

In order to eliminate the effects of practice and of personal differences in skill, the mean chain-assembling time in the first *three* 20-minute periods was taken as 100, and the individual times were calculated in relation to it. The average results are plotted in Fig. 12, and it will be seen that at a cooling power of 7·0 the chain-assembling time fell rapidly during the first four 20-minute periods. This must have been due to the effects of practice during the session, as the hand temperature remained nearly steady at 82° ; but when it fell to 80° in the last period before the break the chain time began to rise, so it appears that the critical hand temperature of the boys was the same as our own. After the break the chain time showed a considerable temporary rise, but it subsequently sank to a minimum of 92·0 at the end of the morning, owing to practice and to warmer hands. The foot temperatures of the boys were taken as well as the hand temperatures, and the figures recorded on the lower side of the curve show that though the feet were about 7° cooler than the hands, they kept at a fairly steady temperature throughout.

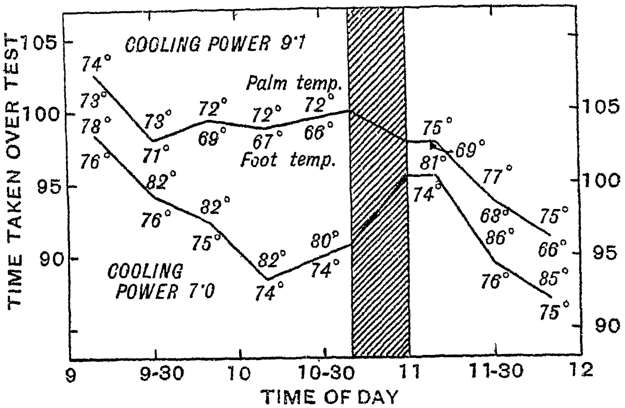

Fig. 12.—Time taken by boys over manual dexterity test in relation to cooling power of air and temperature of hands.

In the observations made at a cooling power of 9·1 the mean chain-assembling time during the first three 20-minute periods was 5 per cent. greater than in the observations at a cooling power of 7·0, so the curve has been plotted at a correspondingly higher level in Fig. 12. It will be seen that the chain time did not improve at all from the second period onwards until the break. After that it rapidly improved, though it was always slower than the times observed at the lower cooling power. The chain time was obviously related to the hand temperature, for this fell to a minimum of 72° during the three periods immediately preceding the break, and then showed a fair rise because of the physical exercise taken during the break. When the hand temperature was at 72° the chain time was about 11 per cent greater than in the other series. As we ourselves showed a 12 per cent. increase of time when our hands cooled to 70°, it follows that these boys were affected by cold hands to about the same extent as we were. It will be seen that the foot temperature of the boys was 7° lower than in the other series of observations, and varied roughly in correspondence with hand temperature.

The boys took, on an average, nearly four minutes to do the chain-assembling test, and they took almost the same time over the arithmetic test. As the time taken over this test was scarcely affected by the cooling power of the air, and as it was very much the same in the three subjects and did not diminish much with practice—for there was a reduction of only 24 per cent. between the beginning and end of the tests—we have merely averaged the times taken in the two series of observations in order to make our comparison. The duration of these times in seconds was as follows :—

Cooling Power of Air.	*Time of Day.*								
	9 0–	9 20–	9.40–	10 0–	10.20–	10 40–	11 0–	11.20–	11.40–12.0
7·1	230	232	230	235	237	break	231	220	219
9·1	241	240	239	227	228	break	222	233	222
% diff.	+5	+3	+4	−3	−4	—	−4	+6	+1

It will be seen that though the time taken in the cool room was rather greater at the outset, it was less later on, and on an average it exceeded that taken in the warm room only by 1 per cent. This difference is statistically insignificant, and therefore it might be thought that a cooling power of 9·1 had no influence on the performance of mental work, whatever effect it may have had on manual work. However, it does not follow that because a subject can perform mental work at full speed for occasional bursts of four minutes, he can sustain the effort equally well for continuous periods of an hour or so. Certainly we ourselves found that when our hand temperatures fell to 70° in consequence of exposure to air at a cooling power of 10, we felt so cold that it needed some mental effort in order to keep our attention on our work.

OBSERVATIONS ON THE HAND TEMPERATURE OF SCHOOL CHILDREN.

Observations were made on the hand temperature of groups of children pursuing the ordinary school curriculum in floor-heated and panel-heated schools, whilst for purposes of comparison another series was made in an ordinary type of school heated by hot-water radiators. This school was designed by Mr. G. H. Widdows in 1906, and it has three pairs of class rooms, separated by a wide corridor. Of the two rooms tested by us, one was 29¼ ft. by 23 ft in area, and the other 24¾ ft. by 20¼ ft., whilst each room was 11 ft. high at the sides and 14 ft. in the middle. The rooms had an excellent system of cross ventilation, the north and south walls each having two large windows 6¼ ft. by 5 ft. in area. The upper two-thirds of each large window consisted of three swivel windows, and the lower third, of three hopper windows. These hoppers were kept open for the most part, and some of the swivels were partly open. Also there were small swivel windows high up on the west or east wall of the rooms. The heating system consisted of two 3½ in. low pressure hot water pipes running round three sides of the rooms (i.e., on all except the corridor side), at an average height of 7 in. above the floor. There were, in addition, two or three radiators close to one wall, rising to a height of 4 ft. above the floor. The mean temperature gradient observed by us during the two days is shown in Fig. 13.

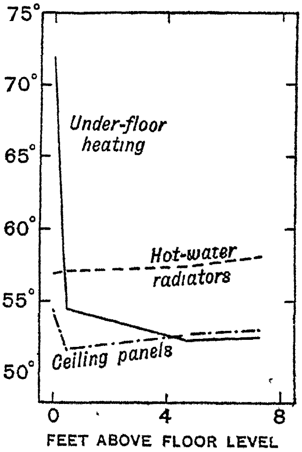

Fig. 13.—Temperature gradients at the schools where the children were tested.

It will be seen that it was nearly steady at all levels, as it ranged only from the lower limit of 57·0° at floor level to the upper limit of 58·2° at the 7 ft. 3 in. level. This low temperature gradient was due to the main source of the heat being only a few inches above floor level, and it is a good instance of the even distribution of heat which can be achieved by a hot water pipe and radiator system when properly designed.

The children in one of the class rooms were about 13½ years of age, and those in the other room 11½ years, they being of both sexes in each room. As the two sets of observations agreed well we grouped them together. We thereby obtained information about the palm temperature of 45 girls and 34 boys. It took us only five to seven minutes to go round a whole class, and it interrupted each child only a few seconds, after the novelty of our test had worn off. The children were in class from 9.0 a.m. to 10.45, when they had a 15-minute break and ran about the playground. They were in class again from 11.0 to 12.0, and from 1.30 to 2.50, when they had another 15-minute break. They ceased work at 4.0 p.m. We tested the children shortly before each break and shortly after their return, as well as in the middle of each session.

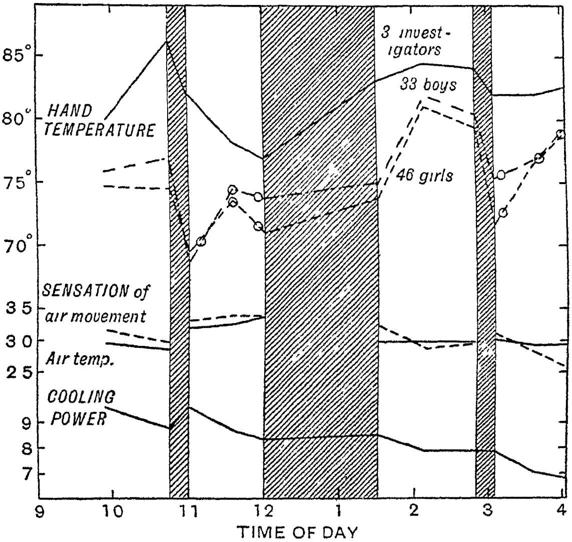

Fig. 14 —Hand temperatures in class rooms with ordinary ventilation, and heated by hot-water pipes and radiators.

The cooling power of the air in each room was estimated at two typical places on opposite sides of the room at 4 ft. 9 in. and 6 in. levels, and a mean taken. It will be seen from Fig. 14 that during the morning it averaged about 9, whilst in the afternoon it was 8 at first and 7 later on. We naturally had to accept the atmospheric conditions as we found them, and we made no attempt to regulate them, but the school staff were alive to the importance of opening windows, and the air in the class rooms kept quite fresh. It will be seen from Fig. 14 that our own palm temperature was usually above 81°, the temperature at which some reduction in our manual dexterity began to develop, but that of the children only once reached this level, and it was usually about 75°. Hence they must have lost a certain amount of manual dexterity.

Our own hands were distinctly warmer than when we made our observations in the floor-heated and stove-heated rooms at a cooling power of 8·3, but this was partly because we were rather more active, owing to our taking the children's hand temperature, and partly because we never sat down in the class room for a longer period than 80 minutes at a time, as contrasted with the 180 minutes in the other rooms. Our sensations of air temperature and of air movement never rose above 3·4, and averaged 3·0 and 3·1 respectively (i.e , they indicated "comfortable" and "medium").

In Fig. 14 and in subsequent figures the points indicating the hand temperature at the end of the morning and at the beginning of the afternoon are joined by straight lines for the sake of clarity, but with one exception no observations of actual temperatures were made in the midday interval.

Our principal observations in a floor-heated room were made for two days on a group of 32 children of both sexes. The class room (24 ft. by 21½ ft. in area) had the whole of the glazed doors fastened back on the north side, which was more or less away from the direction of the prevailing wind, and all the hoppers on the south side were open. The temperature of the air outside averaged 43° on the first day and 46° on the second day, but owing to the stronger wind, the cooling power of the air was greater on the second day than on the first. The children sat in four rows, nine of them in the warmest row, 3 ft. from the south side, and eight in the coldest row, 3½ ft. from the open doors, the remainder being in the middle two rows. One investigator made kata observations in the middle of the warm row and another in the cold row, whilst the third investigator sat in the middle of the room. The mean temperature gradient observed during the two days is shown in Fig. 13.

The observations made on the windy day are the most instructive, and will be considered first. Work started at 9 a.m., and the mid-morning break, with its opportunity for physical exercise, came at 10.35–10.50; but on some days there was a period of physical drill in the earlier part of the morning. It will be seen from Fig. 15 that during both morning and afternoon the hand temperature of the investigators rapidly fell, and at 2.0 p.m. it reached 70°, the temperature previously found to correspond to a reduction of 12 per cent. in manual dexterity. By 4.0 p.m. the temperature had fallen to 65°, and the loss of manual dexterity must have been very much greater. The sensation of air temperature had meanwhile fallen to 5·0, indicating the maximum sensation of coldness on our scale. All three of us were, in fact, miserably cold. But what about the children? For the sake of clarity, we have plotted only the hand temperatures of the inner and outer rows of children, but those of the intermediate rows gave an intermediate result. It will be seen that in the afternoon session—which gave the most closely comparable results as we and the children all started with similar hand temperatures—the inner row maintained a higher hand temperature than we did, whilst the outer row had rather a lower one. On an average, the whole 32 children had a temperature of 73·0° in the first half of the afternoon and 66·1° in the second half, whilst our own temperatures were 70·8° and 65·7° respectively. It is not likely that the children felt the cold so much as we ourselves did, as they were acclimatised to the atmospheric conditions, but judging by our personal feelings there can be no manner of doubt that they were too cold, and that their capacity for profiting by the school instruction was thereby impaired. We noted, in fact, that some of them were inattentive, and frequently tried to warm their hands by friction, putting them in their pockets, or sitting on them. The plan of opening all the doors on one side of the class room reacted very unequally on the various children, for though the cooling power of 9·7 experienced by the inner row might have been borne with equanimity, that of 14·0 experienced by the outer row must have been very trying. Hence it would have been better, on this particular occasion, to have closed all the doors, and have relied on the opening of hoppers and window flaps. Thereby an equalised cooling power of about 9 would have been obtained.

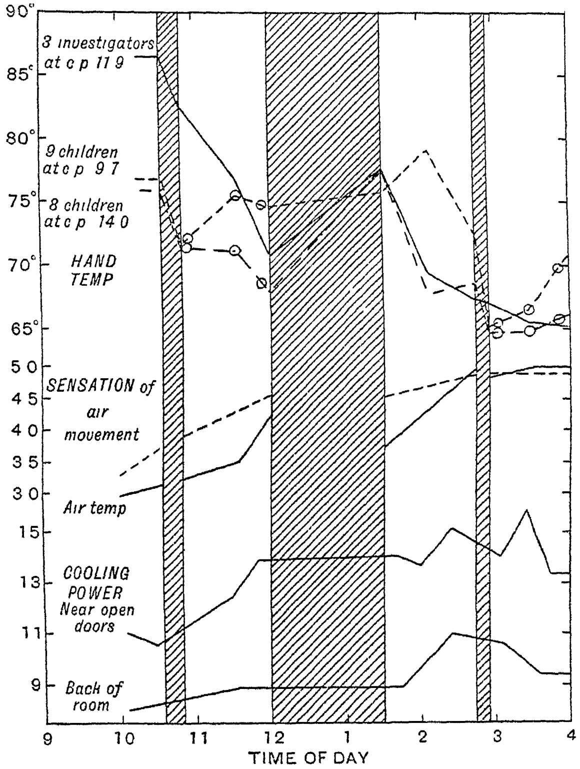

Fig. 15.—Hand temperatures in class room with open-air ventilation and under-floor heating.

The 10 or 15-minute breaks in the middle of the morning and afternoon are of great value to the children in stimulating the circulation. The children rush violently about the playgrounds, kicking a football, skipping, etc., and it will be seen from Fig. 14 that on their return their hand temperature was usually low at first, but subsequently it improved considerably. The low temperature was due to the direct effect of the cold outside air, whilst the subsequent rise was a reaction to the violent exercise. In the semi-open-air school the inner row of children showed the same reaction as the children at the ordinary school, but the outer row of children did not, as their circulation could not cope with the cold to which they were subjected.

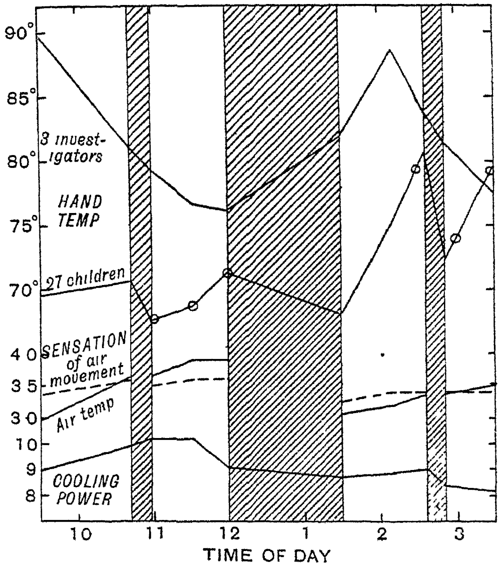

Fig 16.—Hand temperatures in class room heated by ceiling panels

The other set of observations made on the 32 children were not so striking, as the cooling power was more steady. It averaged 9·5 for the inner row and 11·1 for the outer. The hand temperatures of the children corresponded closely with our own, and our sensation of air temperature reached the mean value of 4·0 (or " too cold ") in the latter half of the afternoon.

Our observations on the effects of ceiling-panel heating were made in the room described previously, and it will be seen from Fig. 13 that the average temperature gradient was very small, except that the floor temperature was 3° higher than that of the air immediately above it. Our observations lasted two days, and they were made on 27 children of both sexes, of the average age of 13·8. They were mentally deficient, having a mental age of about 7 to 8, but they appeared to be physically normal. It will be seen from Fig. 16 that the cooling power of the air ranged from

9·2 to 10·2 in the morning, and from 8·2 to 9·0 in the afternoon. All the swivel windows on both sides of the room were kept open to a moderate extent, and the mean velocity of the air current was 27 ft. per min. at head level, and 31 ft. at floor level. The hand temperature of the children was always considerably below that of the three investigators, except at the end of the afternoon, and it fell to 68° in the morning, when the air had a cooling power of 10·2. It will be noted that the children had shorter school hours than those previously described, for they worked only from 9.30 a.m. to 12, and from 1.30 to 3 30 p.m., whilst breaks of 12 to 15 minutes cut up the actual working time into periods of 43 to 73 minutes.

These mentally deficient children often did manual work in the garden and workshop, and an excellent dinner was provided for them at the school. The two groups of children previously described were not provided with dinner, and there can be little doubt that some of them were suffering from under-nutrition, as there was a good deal of short time among the industrial workers of the district, chiefly miners. All three sets of children wore their ordinary indoor clothing, without any overcoats, gloves, etc., and so did the investigators.

So far we have referred only to the average hand temperatures of the children, but as might be expected, great variations are shown by the individual children. Some idea of these variations can be gathered from Table IV, where the relative frequencies with which various temperatures occurred are recorded as percentages. The observations made in the last 60 or 70 minutes of the morning and afternoon sessions (marked with a circle in Figs. 14, etc.) are alone included, as it was thought that only by then had the children got more or less into equilibrium with the atmospheric conditions to which they were exposed. The observations made at the hot-water radiator-heated school are the most reliable, by reason of their number, and we have split them into two groups, according as they were made at an average cooling power of 7·2 or one of 9·0. We see that at the lower cooling power the hand temperatures averaged 76·1°, and therefore indicated a small loss of manual dexterity, whilst of the individual observations 18 per cent. indicated a lower hand temperature than 70°. Such a temperature was found, both by the three investigators and by the three boys tested, to induce considerable personal discomfort and considerable loss of manual dexterity, and though it is possible that people who habitually suffer from cold hands would not be greatly affected, there can be little doubt that, speaking generally, temperatures below 70° are too cold and ought to be avoided. Hence the cooling power of the air ought not to be raised so high as to induce these low temperatures in more than a small proportion of the persons subjected to it. For instance, we see that in air at a cooling power of 9·0, 42 per cent. of the children had a hand temperature below 70°. Such a high proportion seems excessive. For the attainment of maximum

TABLE IV.—FREQUENCY OF OCCURRENCE OF VARIOUS HAND TEMPERATURES IN CHILDREN ATTENDING SCHOOLS WITH VARIOUS FORMS OF HEATING.

—			Hot-water radiators (age 12½).		Ceiling panels (age 13⅔).		Under-floor (age 11).			
Number of different children			79	79	27	27	9	32	21	8
Number of observations			194	237	181	133	81	210	63	24
Mean atmospheric conditions at head and foot levels.		Dry kata cooling power	7·2	9·0	8·5	10·1	9·1	10·5	12·5	14·4
		Temperature	60·1°	54·9°	53·9°	49·6°	56·2°	52·6°	53·6°	50·0°
		Velocity (ft. per min.)	27	38	27	35	46	56	116	140
Per cent. of children with hand temperature	too cold	Under 60°	—	—	—	2	2	1	5	8
		60° to 64°	1	8	1	30	6	15	35	50
		65° to 69°	17	34	11	43	31	38	32	29
		70° to 74°	32	30	38	12	31	32	21	13
	probably warm enough.	75° to 79°	26	14	19	8	20	9	3	—
		80° to 84°	8	9	19	3	9	4	3	—
		85° or more	16	5	12	2	1	1	1	—
Mean hand temperature			76·1°	72·3°	77·7°	68·2°	72·1°	69 8°	67·3°	64·7°

manual dexterity, such as is needed by many industrial workers, a hand temperature of 75° or more is desirable, and we have therefore marked such temperatures in the table as "probably warm enough", without committing ourselves as to the correct designation for hand temperatures of 70° to 74°.

The observations made at the panel-heated school were likewise divided into two groups, according as the cooling power averaged 8·5 or 10·1, whilst those at the floor-heated school, where the range of cooling power experienced was much wider, were divided into four groups. The children tested at a cooling power of 9·1 showed a similar distribution and a similar mean hand temperature to those tested at the same cooling power at the hot-water radiator-heated school. The hand temperatures observed at higher and higher cooling powers fell in steady proportion, as can be seen from the mean temperatures plotted in Fig. 17. Another set of observations was made in another floor-heated school upon 37 infants of the average age of 6, and the mean results obtained are recorded in the Figure.

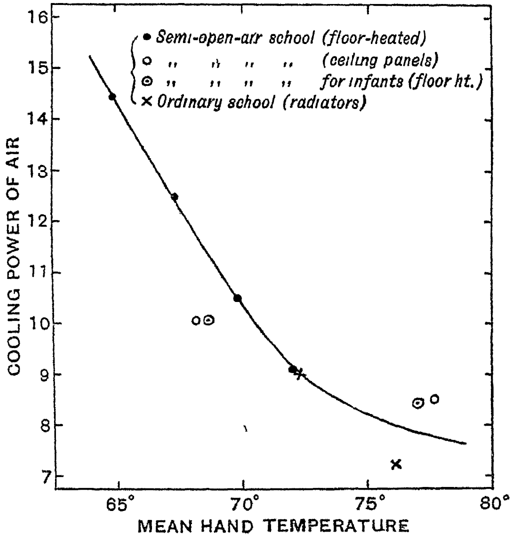

Fig. 17.—Relationship between mean hand temperature of children at various schools and cooling power of air.

In order to assist comparisons, a curve giving the best fit has been drawn through the ascertained points, and it cannot be said that they give any very definite indication in favour of one system of heating as against another, though the observations made in the hot-water radiator-heated room at a cooling power of 7·2 suggest that the hand temperatures then observed were lower than they would have been in floor-heated rooms. This conclusion agrees with that previously arrived at, which indicated that a floor-heated room feels distinctly warmer than a stove-heated room (i.e., a room which is not floor-heated).

OBSERVATIONS ON CHILDREN ATTENDING OPEN-AIR SCHOOLS.

The results described above appear to indicate that for the attainment of full efficiency at work, school children ought not, as a rule, to be subjected to air with a cooling power much above 7, and in any case, not above 9. How can this conclusion be reconciled with the fact that true open-air schools, with little or no artificial heating, act most advantageously on the health of debilitated children, and especially on those suffering from surgical tuberculosis? Though we had no intention of making a thorough investigation on children attending open-air schools, we thought it desirable to make a certain number of observations so as to clear up the apparent contradiction, in so far as one exists. Our most striking results were obtained at the new open-air school at Nottingham, which is described in the "Medical Officer" (1926). There are four class rooms, each 24 ft. by 23 ft. in area, and they have a low wall, 30 in. in height, all round. Two of the rooms have a brick wall on the E. or W. side, and a wall with large windows on the N side, whilst the other two sides are open. The other two rooms are open on all sides, but stout canvas blinds can be pulled down on any side so as to exclude rain and wind, and similar blinds are provided on the two open sides of the more protected class rooms Each room has a brightly burning anthracite stove, which looks cheerful, even if it does not afford much warmth to the children. The children attend the school from 9.30 a.m. to 6.30 p.m. for eight months of the year, and have a good breakfast on arrival. Dinner is provided at 12.30, followed by a rest on a trestle bed for an hour, and tea comes at 4.30, but in the winter months (Dec. to Mar.) the children go home at 4.15, and do not have tea at the school. Also the children have cod liver oil twice daily. We found that all the children were warmly clad in outdoor clothing, and if any child lacked an overcoat, there was a plentiful stock at the school for lending.

We observed a class of 16 girls (aged 12¾) on a day when it was 5° below freezing point outside, whilst the temperature in the class room averaged freezing point. All the canvas blinds were pulled down, though there was plenty of light in the room from the windows and from the gap in the canvas blinds over the low entrance doorway. The effect of the low wall and the blinds in reducing the cooling power of the air was remarkable, as can be gathered from the following mean data :—

Air outside had c.p. of 26·8 (= temp. of 27·3° and vel. of 254 ft. per min.).

Air in room had c.p. of 15·0 (= temp. of 32·0° and vel. of 41 ft. per min.).

The children returned from breakfast at 9.55, and sat at work for 38 minutes, after which they had physical exercise for 11 minutes. They repeated the system of sitting down for about half-an-hour, alternating with about 10 minutes' exercise, during the morning and afternoon. The duration of the alternations in minutes was as follows :—

Sitting at work	38		32		31		37		30		32
Exercise, etc.		11		16		(143)		5		5	

The 143 minutes' interval included dinner, lying down, and two periods of exercise. The hand temperatures of the children are recorded in Fig. 18 and in Table V. It will be seen that

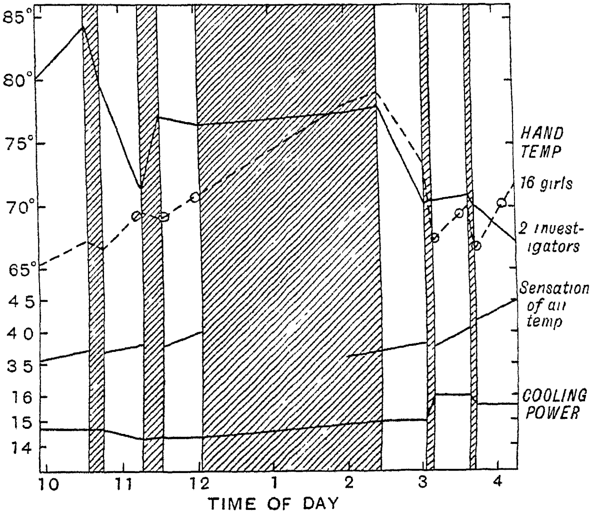

Fig. 18.—Hand temperatures in screened open-air school.

shortly after breakfast the temperature was only 66°, but it rose steadily in the course of the morning till it reached 71° just before the long break, the kata cooling power then being 14·4. At 2.0 p.m. we took the hand temperature whilst the children were still lying down, well wrapped up, and it then averaged 78°. On resuming afternoon work the temperature soon fell, and kept at about 69° during the latter two-thirds of the afternoon, when the cooling power of the air was 15·8. It is evident, both from the gradual rise of hand temperature in the morning from its low initial value, and from the fall in the afternoon from its high initial value, that the equilibrium hand temperature was about 70°. This is considerably higher than the temperature observed in the children attending the floor-heated school when the air was at a cooling power of 12·5 to 14·4. The chief reason of the difference observed depends on the short sittings of the open-air children (averaging only 33 minutes), and their alternation with periods of physical exercise. The children in the floor-heated school had to sit still for periods averaging 77 minutes, and therefore they had plenty of time to cool down. Also they did not wear extra clothing, such as overcoats, ulsters and gloves, and were not provided with meals by the school.

TABLE V.—FREQUENCY OF OCCURRENCE OF VARIOUS HAND TEMPERATURES IN CHILDREN ATTENDING OPEN-AIR SCHOOLS.

—			Protected open-air in sun (age 8½).	Semi-open-air (age 13).		Protected open-air (age 12¾).			Exposed open-air	
									(age 10).	(age 8¾)
Number of different children			30	19	19	20	16	15	43	24
Number of observations			89	55	56	40	46	58	128	117
Mean atmospheric conditions at head and foot levels.	Dry kata cooling power		<11·8	10·5	11·1	14·1	14·4	15·8	15·2	18·2
	Temperature		38·7°	45·4°	44·0°	49·8°	32·7°	31·8°	32·5°	36·6°
	Velocity (ft. per min.)		51	26	30	129	36	52	44	123
Per cent. of children with hand temperature	too cold	Under 60°	—	2	5	2	2	3	42	49
		60° to 64°	11	16	36	28	20	38	31	38
		65° to 69°	25	26	29	35	41	24	18	11
		70° to 74°	21	26	16	15	15	19	5	2
	probably warm enough	75° to 79°	20	16	7	10	11	9	2	—
		80° to 84°	12	7	5	5	9	5	1	—
		85° or more	11	7	2	5	2	2	1	—
Mean hand temperature			74·7°	72·9°	68·1°	69·4°	69·7°	68·5°	62·1°	60·3°

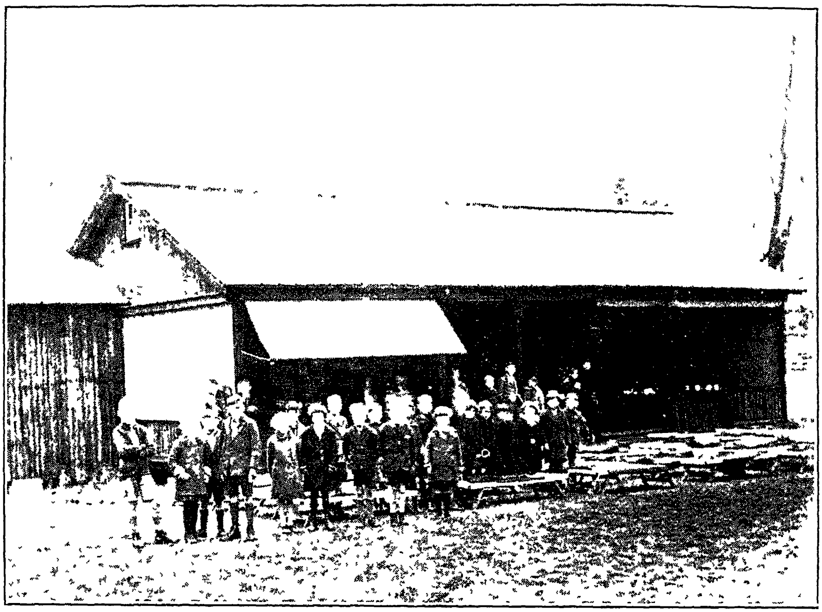

Fig 19 —Open-air school showing low wooden screens and canvas blinds, one of the latter being used as a sun blind

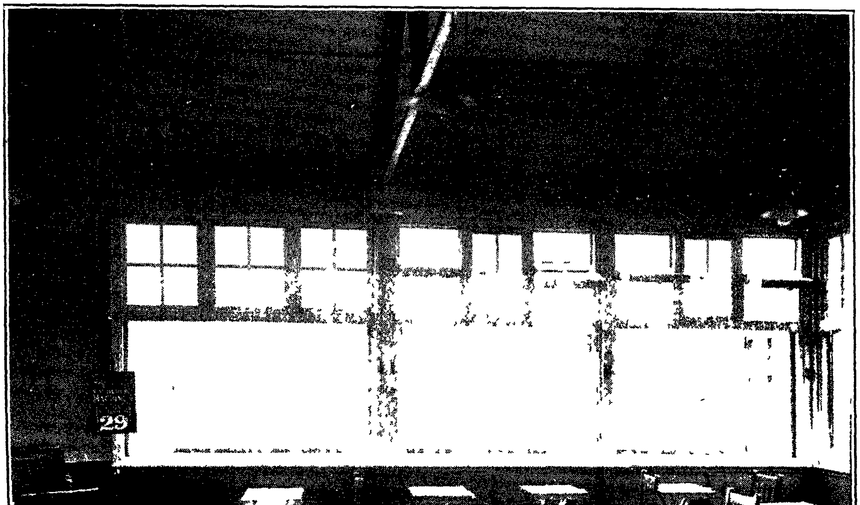

Fig. 22.—Semi-open-air class room heated by hot-water pipes and radiators, and by open coal fire

The children at the open-air school, though they obviously felt the cold, kept to their work fairly well. Some of them had woollen gloves on even when writing, whilst others wore mittens Taking the whole day through, with its shortened hours of work, they probably did about half as much work as children in well-warmed schools would have done, but of course we cannot assume that their mental development was retarded in anything like a corresponding proportion.

The effect of the canvas blinds in reducing the cooling power of the air is well shown by the observations made on another day when the air of the room was 17° warmer. Only a quarter of all the blinds were then pulled down, and consequently there was a considerable amount of air movement and the cooling power of the air was almost the same as before. The mean hand temperature (taken in the latter part of the sessions) was likewise nearly the same, as can be gathered from the mean data here adduced, and from the frequency data given in Table V.

January 31st.—Twenty girls had hand temp. of 69·4°, c.p. being 14·1 (= temp. of 49·8° and vel. of 129 ft. per min.).

February 27th.—Sixteen girls had hand temp. of 69·7°, c.p. being 14·4 (= temp. of 32·7° and vel. of 36 ft. per min.).

The effect of the blinds in reducing cooling power was almost as great in the class rooms without any containing walls (except the low wall all round) as in the rooms with two walls. This is shown by the following mean figures :—

Position of Blinds.	*Cooling Power inside Room.*	*Cooling Power outside.*
All down ..	.. 13·1 (S.E room) ..	27·1
7 down and 1 up	.. 13·6 (S E. room) 14·5 (S.W. room)	30·7
6 down and 2 up	.. 14·1 (S.W. room) ..	24·3

Further observations on the effect of blinds and screens in reducing air movement were made at a new school at Oxford. Apart from the cloak room and kitchen, this school consisted of a single large room 42 ft. by 21½ ft. in area. Rising from the floor were low wooden screens (28 in. in height), which could be removed when thought desirable. Canvas blinds could be pulled down so as to fill the gap between roof and screen, or they could be stretched forward so as to form sun blinds, as is shown in Fig. 19, where the blinds are pulled down at the E. and W. ends of the room, and one of the blinds on the S. aspect is arranged as a sun blind.

Observations were made on a cold day when a moderate East wind was blowing, when (*a*) all the blinds were pulled down, except the middle one on the S. aspect, where the usual entrance to the class room came; (*b*) all the S. blinds were up, but the E. and W. blinds were down; (*c*) all the blinds were up; and (*d*) the wooden screens were removed in addition. Observations were made at 4 ft. 9 in. and 6 in. levels at two typical spots in the class room, and after the series of observations was completed, it was worked through again in reverse order. The means of the observations are recorded in Table VI. Here it will be seen that when the outside air had a velocity of 280 ft. per minute (the mean of numerous observations taken during the course of the other observations), it was reduced to 21 ft. per minute by the blinds and screens, whilst the cooling power of the air was reduced from 23·5 to 11·5. No doubt the effect of the blinds depends on the direction and force of the wind, but probably the results recorded in Table VI are a fair average. As the mean of 190 observations made in winter time outside factories situated in various parts of the country, we found an average air velocity of 403 ft. per minute; but the median velocity was 290 ft., or almost the same as that observed in the present series. Also the effect of the blinds and screens on cooling power was similar to that observed at the Nottingham school.

It will be seen from the table that the raising of the E. and W. blinds caused the air currents to increase fourfold, whilst the removal of the wooden screens did not cause much further increase. The air velocity at floor level was usually rather greater than at head level, in spite of the protection of the low screens. A similar result was observed on another day, when series of observations were made whilst the children were present in class. The blinds on the E. and W. ends of the room were then drawn down, but those on the S. side were up. The mean air velocity was 37 ft. per min. at head level, and 45 ft. at foot level. At the Nottingham school the observations made in the rooms with two protecting walls (and blinds mostly drawn down) gave a mean velocity of 38 ft. at head level and of 58 ft. at foot level; but those in the rooms without protecting walls (but with blinds mostly drawn down) gave one of 39 ft. at head level, and 25 ft. at foot level. On an average, therefore, the air currents were distinctly greater at foot level than at head level, in spite of the low walls and screens.

The only artificial heating in the single-room school consisted of two small oil stoves, which cannot have raised the temperature more than a degree or two. The 30 to 40 children attending the school were of the average age of 8½. They arrived at 9 a.m. and had breakfast shortly after. Dinner was at 12.15, followed by an hour's rest on trestle beds (*cf.* Fig. 19), and tea was at 4.15. We made observations on a cold day (February 28) when the air outside had a mean cooling power of 22·7 and a temperature of 30·8°, whilst the temperature of the air in the class room was 35·5°. The blinds at the E. and W. ends were drawn down, but those on the S. side were up, so as to admit the sun, which shone brightly all day. It must have warmed the children a good deal, as roughly two-thirds of them sat in sunlight. The mean kata cooling power was 13·7 when taken in the shade, but when observations were made alternately in sun and shade

TABLE VI.—INFLUENCE OF BLINDS AND LOW WALLS ON AIR CURRENTS IN OPEN-AIR SCHOOL.

Conditions	At 4 ft. 9 in. level.			At 6 in level.			Mean.		
	Cooling power.	Temp.	Air vel.	Cooling power.	Temp.	Air vel	Cooling power.	Temp.	Air vel.
(*a*) All blinds down but middle one (S.)	11·3	38·5°	18 ft.	11·7	38·7°	23 ft	11·5	38·6°	21 ft.
(*b*) All S. blinds up	13·7	38·5	46	14·0	38·8	53	13·9	38·6	50
(*c*) All blinds up	19·6	38·0	176	21·1	38·2	215	20·4	38·1	196
(*d*) Blinds up and low walls removed . .	22·4	38·0	247	21·0	38·3	213	21·7	38·1	230
Air outside	23·5	38·1	280	—	—	—	23·5	38·1	280

at adjacent spots, it was found that a sunless cooling power of 14·0 was converted into a sun reading of 11·8. Hence the cooling power data recorded in Fig. 20 and Table V are too high, and probably ought to be reduced by something like two units. It will be seen that the hand temperature of the 30 children tested remained at about 66° for the first half of the morning, but after a 36-minute period of exercise and singing the temperature went up to 76°. Therefore it was never in approximate equilibrium with the atmospheric conditions and with average periods of work and exercise. In the afternoon the hand temperature of the children remained fairly steady at about 75°, which is remarkably high for the (shade) cooling power of 11·8 observed, and would still be very high if we assume that the effective cooling power, after allowing for the sun, was about 10. However, the influence of the sunlight would be greater than that suggested by the reaction of the katathermometer ; but in any case it is remarkable that the children kept so warm when the outside air had a temperature of 33°, and they had to sit for 55 minutes without any physical exercise. The investigators, who were clad in overcoats, felt the air to be only slightly " too cold " (mean, 3·3), and their hand temperature in the afternoon was rather lower than that of the children. It will be seen from Fig. 20 that the distribution of sitting-down periods and of exercise periods was not so regular or so well arranged as at the Nottingham school. The children were warmly clad, and kept to their work well most of the time.

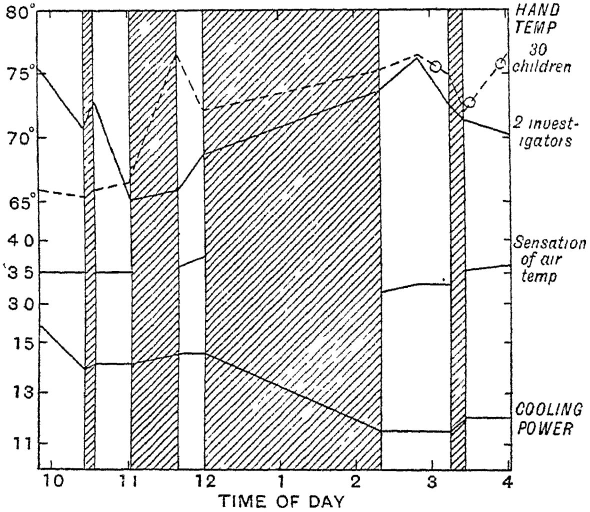

Fig 20.—Hand temperatures in open-air school (screened, and exposed to sun all day).

Two other sets of observations were made at the London school for mentally deficient children previously referred to, for there were, in addition, other buildings fitted up for the open-air instruction of children suffering from physical debility. The majority of these children were kept under a shed which ran from E. to W., and had no protecting walls to it, except on the E. side, though there was a high wall about 12 ft. from the shed on the N. side. Also light canvas screens, 4 ft. in height, were sometimes fixed at the S.W. corner of the platform under the shed. The hours of work were from 9 30 a.m. to 11.45, and from 2.0 to 3.30 p.m., with a fairly long break interposed in mid-morning and mid-afternoon. The children had an excellent dinner at the school, this being served in an unheated dining hall. Afterwards they lay down for three-quarters of an hour in the shed on canvas stretchers raised a few inches above the floor. In cold weather they were wrapped in a blanket, and they could also use this blanket during class, if they desired it. Most of the children were warmly clad in overcoats, ulsters and mufflers. Also a good many of them wore woollen gloves at times.

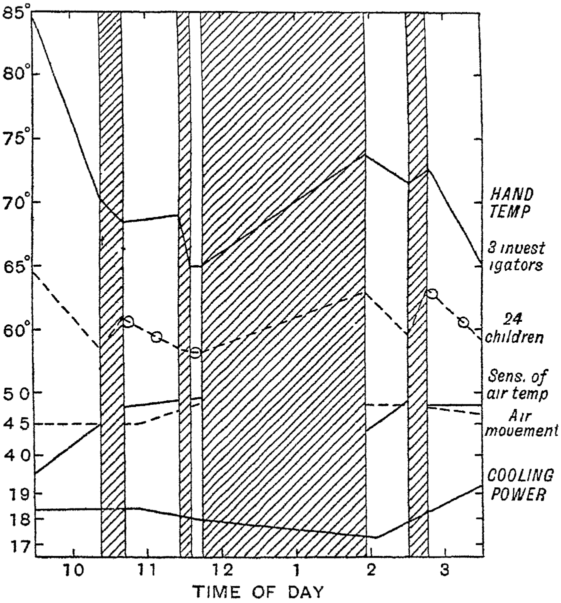

Fig 21.—Hand temperatures in exposed open-air school.

We tested these open-air children on two days, on the first of which the air temperature averaged 36·6° and the air velocity 121 ft. per minute. The dry kata cooling power averaged 18·0, and remained fairly steady throughout the day, as can be gathered from Fig. 21. We took the hand temperature of a group of 24 younger children, whose age averaged $8\frac{3}{4}$, and we found that it never exceeded 63° on an average, and it sometimes fell to 59°. The children were so miserably cold that they could pay very little attention to their work, and they did less than an hour's useful work during the entire day. The teacher did her best for them by allowing them to use their blankets, by letting them clap their hands at times, and by giving them an extra run in the playground towards the end of the morning, in order to warm themselves up; but judging from the hand temperature test, they could not get warm. It will be seen from Fig. 21 that after each break the hand temperature rose a few degrees, but never to a confortable level, and from Table V we see that only in 2 per cent. of the observations was the temperature above 70°. We ourselves, though clad in warm outdoor clothes and though walking about nearly all the time, had a hand temperature of 65° at the end of the morning, and one of 68° at the end of the afternoon, whilst our sensations of air temperature and air movement averaged 4·7 to 4·9 (i.e., almost "much too cold" and "very fresh").

The children tested sat at the W. end of the shed, where they were to some extent protected by the screens, but the other class of older children got no protection as they sat either at the other end of the shed or in the playground outside, in order to catch the sunlight. Here the dry kata cooling power of the air averaged 25·3, the air velocity being 310 ft. per minute.

When we made our tests on another day the atmospheric conditions were less trying, as the cooling power of the air averaged 15·2. The air temperature was lower than before (viz, 32·5°), but the air was comparatively calm, having a velocity of only 44 ft. per minute. We took the temperatures of 43 children of the average age of 10, but ranging from 7·6 to 14·0. Four sets of observations, made in the morning, gave a mean hand temperature of 62·1°, and it will be seen from Table V that 9 per cent. of the children had a temperature of 70° or more The children were able to pay more attention to their work than on the previous day, but they evidently felt the cold a good deal.

It may be wondered why these open-air children compared so badly with the children at the Nottingham school, for it will be seen from Table V that in air at a cooling power of 15·2 their hand temperature was 6° lower than that of the Nottingham girls exposed to air at a cooling power of 15·8. The difference may have been due partly to the children being 2¾ years younger, for our evidence, though not sufficient to be conclusive, suggested that young children did not stand the cold so well as the older ones. Probably it was due partly to the nutrition of the children not being so good, as these children got only their dinner at the school, and not breakfast and tea as well, like the other children. Also they did not appear to be quite so warmly clad. Usually their sitting-down periods were distinctly longer, as they varied from 42 to 57 minutes on the two mornings tested. When they rested after dinner they lay down in the exposed shed, and though wrapped in a blanket the cooling power of the air was too great to enable them to get really warm, as they did at the other two schools.

Another group of the debilitated children at the school were kept under semi-open-air conditions in a warmed class room. The room, 24 ft. by 24 ft. in area, was heated by a large open coal fire at one corner, and by two hot-water radiators (each 42 in. by 30 in.) with two connecting 1½ in. pipes which ran round three sides of the room 6 in. above floor level. Three sides of the room had walls 3 ft. in height, above which were a continuous series of windows 6 ft. in height (*cf.* Fig. 22). These windows were kept open to a considerable extent, and on the day when we made our observations the air temperature in the room averaged 45°, or 6° above the outside temperature. As can be gathered from Fig. 23, the cooling power of the air varied from 13 to 11 in the morning and from 11 to 10 in the afternoon.

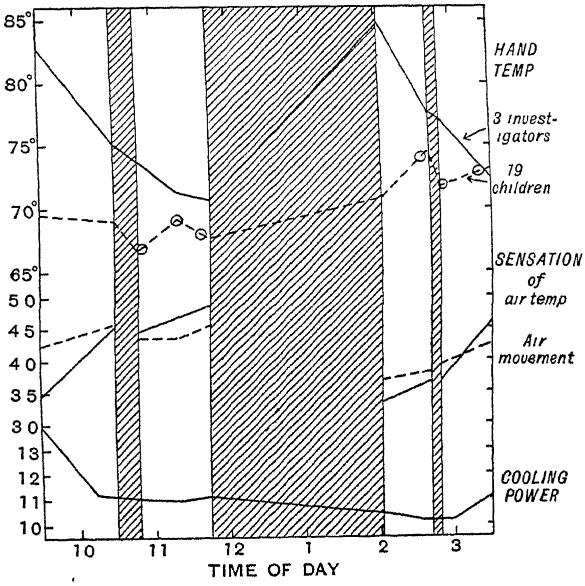

Fig. 23.—Hand temperatures in semi-open-air class room heated by hot-water radiators and coal fire

The average hand temperature of the 19 children (aged 12·10) who were tested was always below 70° in the morning, but rose to 73° in the afternoon. The distribution of temperatures observed during the last hour of the morning and afternoon sessions is recorded in Table V. The children appeared attentive to their lessons, and worked well. All the girls wore ulsters, whilst the boys mostly had mufflers on, and some of the children of both sexes put on woollen gloves at times. All the children had a very good dinner at the school, and lay down in the exposed open-air shed for three-quarters of an hour after it. The investigators (who wore no overcoats) felt the cold a good deal, and their sensations of air temperature and movement rose to 4·9 and 4·5 respectively at the end of the morning. However, their hand temperature was well above that of the children.

No doubt the open-air children get to some extent acclimatised to the cold, but we could not obtain much evidence of it. In Fig. 24 we record the mean hand temperatures, in relation to cooling power, which were observed at the open-air schools. For purposes of comparison we reproduce the mean curve from Fig. 17, which is founded on data obtained in various schools where the children wore ordinary clothing, and—with one exception—had no special dinner supplied them. It will be seen that the hand temperatures observed at the London school at cooling powers of 15 and 18 are in fairly good agreement with the curve, or rather with its upward extension. A mean of the two values observed at the semi-open-air school (London) would also be in fairly good agreement, but the three sets of observations made at the Nottingham school show a hand temperature about 5° above that indicated by the mean curve. The set of observations made in the single-room school indicate a similar excess of hand temperature, even when an allowance is made for the warming effects of the sun, so we may conclude that the open-air children did, as a whole, stand the cold better than the children in warmed school rooms. Much of this apparently increased resistance, and perhaps nearly all of it, was due to the fact that the children were warmly clad, they were specially fed, and, most important of all, they sat at work for shorter periods than the children

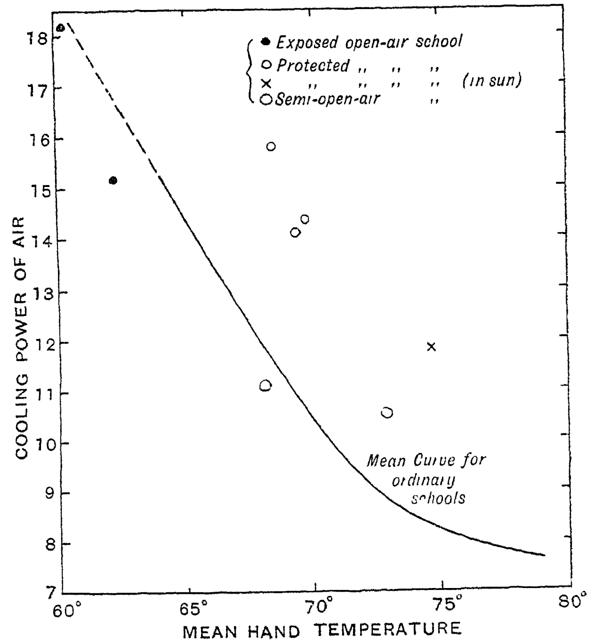

Fig 24.—Relationship between mean hand temperature and cooling power of air in open-air schools (extra clothing, extra feeding, short work periods).

in the warmed schools. In order to find out if the children showed any genuine acclimatisation, apart from these adventitious aids, we split into two groups the children kept in the shed at the London school, according as they had (*a*) been at the school during the whole winter season 1927–28, as well as in the month or two of winter up to the time (December 10–14) when we made our observations, or (*b*) had entered the school in the summer or autumn of 1928, and had therefore had a much smaller experience of winter weather. On an average, the former group of children had a hand temperature which was 2·0° in excess of the latter group on the first day, and 0·4° in defect of it on the second day. Probably the discrepancy was dependent on the fact that the children changed their positions, and some were more protected by the screens than others ; but in any case the difference is too small and irregular to be significant

Probably the acclimatisation depends more on the children getting used to cold hands and feet, than to their bodies reacting physically so as to keep these members warmer.

ABSENTEEISM IN RELATION TO TYPE OF SCHOOL.

There is evidence to show that the health of school children is influenced by the atmospheric conditions of the schools at which they attend. Such variations of health are reflected in the attendance rate of the children though it is by no means permissible to assume that the whole of their absenteeism is due to sickness. Still, this absenteeism affords useful information quite apart from specific knowledge of its causation, so we made an extensive enquiry into absenteeism at the Derbyshire schools, and obtained attendance data for the three years April, 1926 to March, 1929, at nearly all of the thirty schools visited. Of these schools, eight were of the semi-open-air type, and we endeavoured, so far as possible, to obtain attendance figures at two or more schools of the ordinary type in the neighbourhood of each open-air school. Four of the schools investigated were for infants, who show a greater absenteeism than the older children, so these schools are excluded from the list recorded in Table VII. The data in this table relate to 6,312 children, of whom 1,352 were at semi-open-air schools. Most of the schools are marked " C," as they were controlled by the Derbyshire County Council, but four were controlled by the Church of England, and one by a colliery company. The average number of children on the register is given for the years running from April to March, whilst the absenteeism was ascertained by subtracting the total number of attendances during each week from the number that could have been made if all the children on the register had attended each session, and expressing this absenteeism as a percentage of the possible attendances. Three of the open-air schools were not ready for occupation in 1926-27, and the attendance data, which are recorded in brackets, are calculated on the

TABLE VII.—VENTILATION, FLOOR SPACE AND ABSENTEEISM AT VARIOUS SCHOOLS.

School.	Con-trolled by	Sex of children.	Average No. of children.	Grade of ventilation.		Square feet of floor per head				Percentage absenteeism in				
						Children on register.		Children in attendance.		1926–7.	1927–8.	1928–9.	Mean.	
A	C	Mixed	312	Semi-open-air		13·6	13·3	14·6	14·5	(6·3)	6·2	7·9	6·8	8·4
B	C	Boys	312	,, ,,		13·6		14·8		(7·5)	7·7	9·2	8·1	
B	C	Girls	306	,, ,,		13·9		15·0		(6·6)	7·4	7·5	7·2	
C	C	Boys	166	,, ,,		12·4		13·8		9·1	9·1	11·5	9·9	
C	C	Girls	184	,, ,,		12·4		14·0		9·4	11·3	13·4	11·4	
D	C	Mixed	72	,, ,,		13·7		14·7		5·9	5·7	9·7	7·1	
E	C	Mixed	311	2·8	2·2	11·7	12·2	12·6	13·3	5·6	6·8	7·9	6·8	7·6
U	C	Mixed	178	2·3		14·7		16·2		8·5	10·5	9·6	9·5	
T	C	Mixed	278	2·1		11·9		12·4		3·4	3·7	4·0	3·7	
F	C	Mixed	199	2·0		13·3		14·3		6·5	5·4	8·5	6·8	
S	C	Boys	314	2·0		10·2		11·3		10·4	9·2	8·7	9·4	
S	C	Girls	280	2·0		11·6		12·8		10·2	10·0	7·4	9·2	
N	Colliery	Mixed	356	1·6	1·5	21·6	13·9	23·4	15·2	6·0	7·5	9·5	7·7	8·9
G	C	Girls	200	1·6		12·7		13·9		9·1	8·7	8·4	8·7	
G	C	Boys	238	1·4		12·0		13·1		7·7	7·9	8·7	8·1	
H	C	Girls	208	1·6		11·3		13·1		13·7	14·7	12·9	13·8	
H	C	Boys	240	1·5		9·6		10·6		8·4	10·5	8·6	9·2	
J	C. of E.	Mixed	96	1·5		19·9		21·9		7·3	10·5	9·3	9·0	
K	C	Boys	237	1·4		12·2		13·0		6·6	5·2	7·5	6·4	
L	C	Boys	359	1·4		11·5		12·6		7·9	7·8	9·5	8·4	
M	C	Boys	342	1·3	1·2	10·3	12·0	11·6	13·3	10·6	12·0	10·8	11·1	10·2
M	C	Girls	345	1·1		11·6		13·0		9·5	11·6	10·6	10·6	
P	C. of E.	Mixed	275	1·3		14·3		15·6		7·0	9·4	8·7	8·4	
K	C	Girls	256	1·2		14·3		15·5		7·8	7·4	8·7	8·0	
Q	C. of E.	Mixed	95	1·2		12·0		13·5		7·7	13·1	11·0	10·6	
R	C. of E.	Mixed	153	1·1		9·4		10·7		11·7	12·0	13·3	12·3	

assumption that they bore the same numerical relationship to the respective attendance data for 1927-29 as that observed in the average figures for all the other schools.

The quality of the ventilation varied a good deal in the schools of the ordinary type, and we endeavoured to assess its value in terms of its scavenging properties. If a room had a considerable area of windows on opposite sides of the room, which were capable of being opened to a large extent, we marked the grading of the ventilation as 2·0, but if there were windows on one side only, with no sort of permanent opening on another side, we marked the grading as 1·0. If a room contained windows on two adjacent sides we graded it between 1·0 and 2·0, according to the degree to which the direct air currents appeared to scavenge the room. Again, if a room with windows on one side had an open fireplace opposite, we graded it 1·2 or 1·3, according to its size. At one school some of the rooms had adequate windows on two sides and smaller ones on the third side, so they were graded 2·8, whilst the floor-heated semi-open-air schools were graded 4·0. It should be understood that our grading indicates only the facilities for air scavenging, and not the degree to which these facilities were utilised. It would have involved a great deal of labour to investigate this adequately both in summer and winter, and we did not attempt it, but we sampled the atmospheric conditions when the children were in attendance during the course of a single month, April, 1929. The results then obtained are recorded in Table VIII.

From the table it can be gathered that we investigated each of the 30 schools, and that altogether we made 220 sets of observations on cooling power and temperature. On splitting up the schools into four groups, according to their ventilation grading, and averaging, we found that the mean cooling power was at a maximum of 9·3 in the semi-open-air schools, whilst in the ordinary schools it fell with fall in the ventilation grading, till it reached a minimum of 7·7 in the schools with a grading of 1·2. The reduction of cooling power was due chiefly to rise of temperature, for the three groups of ordinary schools showed almost exactly the same air velocity, viz., 38–39 ft. per minute. However, the figures recorded in the column on the extreme right of the table show that this air velocity was maintained only with difficulty in two-thirds of the schools. The figures in question indicate the area of open windows, flues, etc., reckoned as a percentage on the total possible ventilation area, and we see that whilst the air velocity of 39 ft. per minute was maintained by opening only 31 per cent. of the ventilation area in the schools graded 2·2, it was necessary to open 58 or 59 per cent. of it in order to create an equal air velocity in the schools with the lower grading. In the semi-open-air schools an air velocity of 48 ft. per minute, or 9 ft. more than that observed in the ordinary schools, was maintained by utilising only 31 per cent. of the

TABLE VIII.—MEAN ATMOSPHERIC CONDITIONS IN VARIOUS GROUPS OF SCHOOLS (APRIL).

Average grading of the ventilation.	Number of schools.	Number of observations.	At 4 ft 9 in. level.		At 6 in level.		Mean			Outside air		Per cent. of ventilation area utilised.
			Temp.	Kata	Temp.	Kata.	Temp	Kata	Air vel	Temp	Air vel. in ft per min	
Semi-open-air ..	8	53	55·4°	9·0	56·3°	9 5	55·8°	9·3	48	46 7°	481	31
2·2	7	58	58·4	7·9	57 9	8·6	58·1	8·3	39	48·0	452	31
1·5	9	53	59·3	7·7	58·6	8·5	58·9	8·1	39	48·0	447	58
1·2	6	56	60·9	7·4	60·1	8·1	60·5	7·7	38	54·6	432	59

TABLE IX.—SEASONAL VARIATIONS IN ABSENTEEISM AT VARIOUS GROUPS OF SCHOOLS.

Number of schools.	Number of children.	Average age of children.	Average grading of ventilation	Per cent. absenteeism in 1927–9.	Relative absenteeism in							
					April-June.		July-Sept		Oct.-Dec.		Jan -Mar	
6	1,352	11·6	Semi-open-air	8·9	90		96		109		158	
6	1,560	11·7	2·2	7·7	86	98	96	107	92	115	126	154
8	1,934	11·2	1·5	9·2	98		108		118		147	
6	1,466	10·9	1·2	10·7	109		117		135		188	

possible ventilation area, so these data, taken as a whole, undoubtedly support the validity of our scheme of ventilation grading.

To return to the discussion of Table VII, it will be seen that the floor area of the class rooms is recorded in two forms, (*a*) in relation to the number of children on the register, and (*b*) in relation to the number of children in actual attendance. On an average, the floor space per child was nearly the same in the open-air schools and in the ordinary schools. The means were 14·5 sq. ft. per child in attendance at open-air schools, and 14·1 sq. ft. for those at ordinary schools.

The absenteeism figures show a mean absenteeism rate of 8·2, 9·1 and 9·4 per cent. in the three successive yearly periods. The causes of this rise were not determined, except that some of the rise in 1928–29 was due to influenza and to the withdrawal of smallpox contact cases. In any case, it is best to rely on the average figures for the three years, and we see that these figures indicate a mean absenteeism rate of 8·4 per cent. in the semi-open-air schools, as against one of 7·6 per cent. in the group of ordinary schools with good cross ventilation. However, the less well ventilated ordinary schools had distinctly higher rates than the semi-open-air schools, the rate for the worst ventilated schools being 10·2 per cent.

Some light on the unexpected excess of absenteeism in semi-open-air schools over that shown by well ventilated ordinary schools is afforded by considering the seasonal variations in absenteeism. In Table IX we record the relative extent of the absenteeism in each quarter of the year, for the years 1927–29, in terms of the summer absenteeism (April to September) of all groups of schools taken as 100. We see that in the two summer quarters the semi-open-air schools and the well ventilated ordinary schools had almost the same low absenteeism rate. In the October–December quarter, however, the semi-open-air schools had a considerably higher rate than the well ventilated ordinary schools, and in the cold January–March quarter the excess was still more marked. In fact, the absenteeism was rather greater than that shown by the *whole* group of ordinary schools, averaged together. The reasons of these very marked differences between the absenteeism at the open-air schools and the ordinary schools in winter and in summer are developed in detail in the next section of this Report, but it may be stated here that they depend primarily on the semi-open-air schools being too cold. The consequent reduction of attendance depends, at least in part, on the restrictive action of the children's parents, and is irrespective of any direct effect on health.

A factor which influences absenteeism to some extent is the age of the children. We split up the attendance data obtained at several of the schools into three or four groups, according to standard, and the results obtained are recorded in Table X.

Table X.—Absenteeism in Children of Various Ages.

School.	Sex of children.	Per cent. absenteeism in standards 5 and 4	Relative absenteeism in standards				Average age of group			
			8, 7, 6.	5, 4.	3, 2.	Infants	8, 7, 6.	5, 4.	3, 2	Infants
C	Mixed	8 8	109	100	97	150	13 3	12·5	8·0	5·7
F	,,	4·8	111	100	117	208	12·9	11·5	10 0	6·8
G	,,	8·1	134	100	94	173	12·6	10·3	8 3	6·0
K	,,	6·4	94	100	90	164	13·3	11·3	9·3	6·3
L	,,	7·0	116	100	121	—	12·5	11·1	10·1	—
M	Girls	9·9	129	100	97	—	13·5	11·7	9·1	—
M	Boys	11·0	117	100	92	—	13·2	11 5	9·6	—
R	Mixed	10·3	119	100	105	89	13·2	11·9	10·0	7·1
	Mean	8·3	116	100	102	157	13 1	11·5	9·3	6·4

Absenteeism usually reached a minimum in children of standards 5 and 4, who averaged 11·5 years in age, so we took their absenteeism figure as 100 in each instance, and recorded that of the other children in relation to it. It will be seen that children of standards 8, 7 and 6, who had an average age of 13·1, showed an absenteeism rate 16 per cent. greater than that of the 5, 4 standard children The younger children, who belonged to standards 3 and 2 in most of the schools investigated, but to standards 3, 2 and 1 or to standard 3 only in one or two instances, showed a slightly greater absenteeism than the 5, 4 standard children. The infants, whose average age was 2·9 years below that of these young children, showed a considerably greater absenteeism, but none of them are included in the data recorded in Table VII. Consequently we have to consider only the older children, and the relative proportions of children of various standards were fairly similar at the open-air schools and at the ordinary schools. The average ages of the children in the four groups of schools are recorded in Table IX, and it will be seen that they do not differ much. Hence it follows that the differences observed in the absenteeism at various schools were not due to differences of age, except in very minor degree.

The greater absenteeism shown by the oldest children than by those of lower standards is probably due to their being kept at home more frequently for reasons not dependent on ill health.

The irregularity of the data recorded in Table VII is undoubtedly due, to some extent, to factors such as the personality of the head master or mistress and the ease of access of the schools. We were able to exclude one or both of these particular factors by comparing the absenteeism of some of the semi-open-air schools in 1927–29 with that observed at the schools which they replaced, though such a comparison did not avoid the introduction of certain other differences in the conditions besides ventilation and heating. The three sets of comparisons made are recorded in Table XI. Open-air school A, which was opened in April, 1927, replaced a temporary galvanised iron structure built on an adjoining site. The absenteeism at the open-air school in 1927–29 was 11 per cent. greater than that observed at the other school in 1926–27, but schools E, P and N, which were located about 1½ miles from school A, showed an absenteeism rate which was 35 per cent. greater in 1927–29 than in 1926–27. Hence the open-air school showed a substantial improvement in a relative sense. The head teachers at schools E, N and P were the same in both comparison periods, whilst that at school A was different.

The open-air school B, which was opened in April, 1927, showed an absenteeism rate in 1927–29 which was 15 per cent. less than that observed in the school it replaced. The old school was a small one with 205 children, whilst the new school has 618 children on the register, as it includes the children drafted from another school in the neighbourhood. The head teachers

TABLE XI.—EFFECT OF REPLACING ORDINARY SCHOOLS WITH SEMI-OPEN-AIR SCHOOLS.

Comparable groups of schools.	Mean percentage absenteeism.		Per cent change between the two periods		
	1926–7 or 1925–6	1927–9 or 1926–9.			
A.—Ordinary in 1926–7; open-air in 1927–9	6·4	7·1	+11		
E.—Ordinary in both periods	5·6	7·4	+32	+35	+ 1 for open-air schools +24 for ordinary schools
N.— „ „ „	6·0	8·5	+42		
P.— „ „ „	7·0	9·1	+30		
B.—Ordinary in 1926–7; open-air in 1927–9	9·4	8·0	−15		
H—Ordinary in both periods..	11·0	11 7	+ 6	+10	
M.— „ „ „	10·0	11·3	+13		
C—Ordinary in 1925–6; open-air in 1926–9	9·2	9·9	+ 8		
F.—Ordinary in both periods..	4·9	6·7	+37	+28	
R.— „ „ „	10·5	12·5	+19		

of these two old schools were transferred to the new school. It will be seen from Table XI that schools H and M, which were situated about a mile from the open-air school, showed a greater absenteeism rate in 1927–29 than in 1926–27. Their head teachers were unchanged during these years.

Open-air school C was opened in August, 1926, and the statistical periods compared run from April, 1925, to July, 1926, for the old school it replaced, and from August, 1926, to March, 1929, for the new school. The change was accompanied by an increase of 8 per cent. in the absenteeism rate, whilst two ordinary schools F and R, which are situated about two miles from the new school, showed a much greater increase of absenteeism in the second comparison period. The head teachers were the same throughout at all three schools.

Taking an average of the three sets of data, we find that the absenteeism at the three semi-open-air schools was 1 per cent. more than that of the schools they replaced, whilst for the same comparison periods the ordinary schools in the neighbourhood showed an average increase of 24 per cent in absenteeism.

THE TEMPERATURES OBSERVED IN THE CLASS ROOMS.

At the Derbyshire schools it was customary to record the temperature of each class room on a chart, the thermometer—which was suspended 5 ft. to 6 ft. above floor level—being read twice daily from half-an-hour to an hour after the beginning of each session. We have no guarantee either that the thermometers were accurate or that they were read accurately, but probably any errors made in either direction roughly cancel out, and we can accept the data quoted as substantially correct. We obtained access to the charts for the months of November to March in the years of 1927–28 and 1928–29, but the records were not always complete. Altogether we obtained records of five semi-open-air schools and 14 ordinary schools for the great majority of the months mentioned. We separated the observations made in the morning and afternoon, and the total number of readings tabulated were the following:—

	Morning.	*Afternoon.*
Semi-open-air schools ..	6,782	6,547
Ordinary schools ..	13,572	12,961

In Table XII we have recorded the frequency of distribution of the various temperatures as percentages, and it will be seen that in November, for instance, the semi-open-air schools showed a morning temperature of less than 50° on 6 per cent. of all occasions, and a temperature of less than 55° on no less than 38 per cent. of all occasions, whilst the temperature was above 60° only on 21 per cent. of all occasions. The afternoon temperatures were somewhat higher, and the average class room temperature was 57·8°, or 1·4° higher than in the morning.

TABLE XII.—DISTRIBUTION OF TEMPERATURES IN THE TWO TYPES OF SCHOOL.

Range of temperature.		November		December		January		February		March		Mean	
		M	A	M	A	M	A	M	A	M	A	M	A
Semi-open-air schools	49° or less	6	2	9	5	11	3	17	9	7	2	10	4
	50° to 54°	32	23	47	40	46	38	39	30	23	17	37	30
	55° to 59°	41	46	37	44	37	52	34	44	41	39	38	45
	60° to 64°	20	26	7	11	5	7	10	16	27	34	14	19
	65° or more	1	3	0	0	1	0	0	1	2	8	1	2
	Mean temperature ..	56·4°	57·8°	54·6°	55·6°	54·3°	55·6°	54·2°	55·8°	57·2°	59·1°	55·3°	56·8°
Ordinary schools	49° or less	5	1	9	3	6	2	12	3	3	1	7	2
	50° to 54°	19	11	28	19	33	16	30	16	17	6	25	14
	55° to 59°	37	32	37	36	39	42	37	40	37	26	37	35
	60° to 64°	30	42	22	35	18	33	17	34	31	44	24	38
	65° or more	9	14	4	7	4	7	4	7	12	23	7	11
	Mean temperature ..	58·4°	60·2°	56·5°	58·6°	56·6°	58·9°	55·8°	58·7°	59·0°	61·7°	57·3°	59·6°

In January and February no less than 57 per cent. of the morning temperatures were below 55°, though this is the lowest limit that we consider to be compatible with full efficiency in the performance of the school curriculum The means of the temperature data for the five months of the two winter seasons are recorded in the last columns of the table, and it will be seen that 47 per cent. of the morning temperatures, and 34 per cent of the afternoon ones, were under 55°. These low temperatures were not due to the weather being abnormally cold, for though in one exceptionally cold month (February, 1929) the temperature was 7·4° lower than the average observed at the meteorological station, Belper, which is the nearest to the schools, the ten months taken together were only 0·4° cooler than the average for the preceding 50 years.

The temperatures observed in the ordinary schools were, on an average, 2·0° higher in the mornings and 2·8° higher in the afternoons, than those observed in the semi-open-air schools, and the percentages of observations falling below 55° were considerably smaller. Still, even in them a third of the morning observations and a sixth of the afternoon ones were below our arbitrary limit of 55°. We do not wish to imply that Derbyshire schools fall behind other schools in respect of temperature. Though statistical information is lacking, it is quite likely that they are as good as, or better than, the average. Thus we read (3) that in Wiltshire, during the months of December, 1928, and January, 1929, no less than 108 schools out of 267 were habitually below 55°. Such low temperatures are not incurred for lack of advice from authorities, for a regulation of the London School Board (1903) states that if the temperature observed in a class room at 9.30 a.m. is below 54° it has to be reported. Again, it is suggested by Kerr (1926, p. 791) that if the temperature falls to 50° or less the children should not be kept at their desks, but should put on their overcoats and be exercised.

In order to ascertain whether the class room temperature had any influence on absenteeism, we classified all the schools, both semi-open-air and ordinary, according to their temperature (the means of the morning and afternoon readings) in each month of the two winters, and calculated the associated absenteeism. The results are recorded in Table XIII, and we see that, taking all the winter months together, a temperature of over 62·5° was observed only in 1·5 schools, on an average, whilst lower temperatures were observed in increasing numbers of schools, till a temperature of less than 57·5° was observed in the maximum number of 7·4 schools. Taking the results as a whole, the absenteeism was lowest at the highest temperatures, but there was very little difference between the results obtained at 60·0°–62·4°, and those at 62·5° and upwards. At 57·5°–59·9°, however, the absenteeism was considerably greater, and at temperatures below 57·5° it was greater still. The mean results are plotted in Fig. 25, and they show clearly the considerable influence on absenteeism of temperatures below 61°.

Table XIII.—Absenteeism in relation to Class Room Temperatures.

Range of temperature.	Number of schools.	November		December		January.		February.		March.		Mean	
		Temp	% absent	Temp.	% absent.	Temp	% absent.	Temp.	% absent.	Temp.	% absent.	Temp.	% absent.
62·5° and over	1·5	63·5°	7·2	63·2°	6·4	62·7°	10·1	—	—	64·1°	12·0	63·4°	8·9
60° to 62·4°	2·8	61·0	9·8	60·7	7·3	61·2	8·3	61·7°	9·6	61·1	11·1	61·1	9·2
57·5° to 59·9°	5·9	58·6	8·8	58·5	11·9	58·0	13·0	58·2	10·7	59·0	11·1	58·5	11·1
Under 57·5°	7·4	56·7	8·2	54·9	9·9	55·5	11·4	55·4	14·0	56·1	14·3	55·7	11·6

It is natural to assume that the increased absenteeism was due to an increase of ill-health provoked by the colder classrooms, but other series of results showed that this assumption is not justifiable. During the months of January to March, 1929,

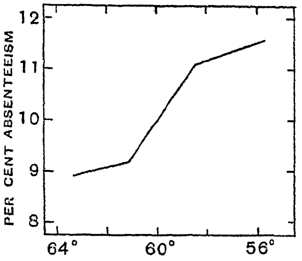

Fig. 25.—Absenteeism in relation to temperature of schools.

we tabulated the daily attendance at the Derbyshire schools, and in addition, at the three unheated open-air schools at Oxford, London and Nottingham. These attendances were expressed as percentages, and the percentages were averaged, so that all schools counted of equal weight, irrespective of their size. The mean results are plotted in Fig. 26, and the true open-air school data, which are recorded in the lower part of the figure, will be considered first, as they are the most instructive. It will be seen

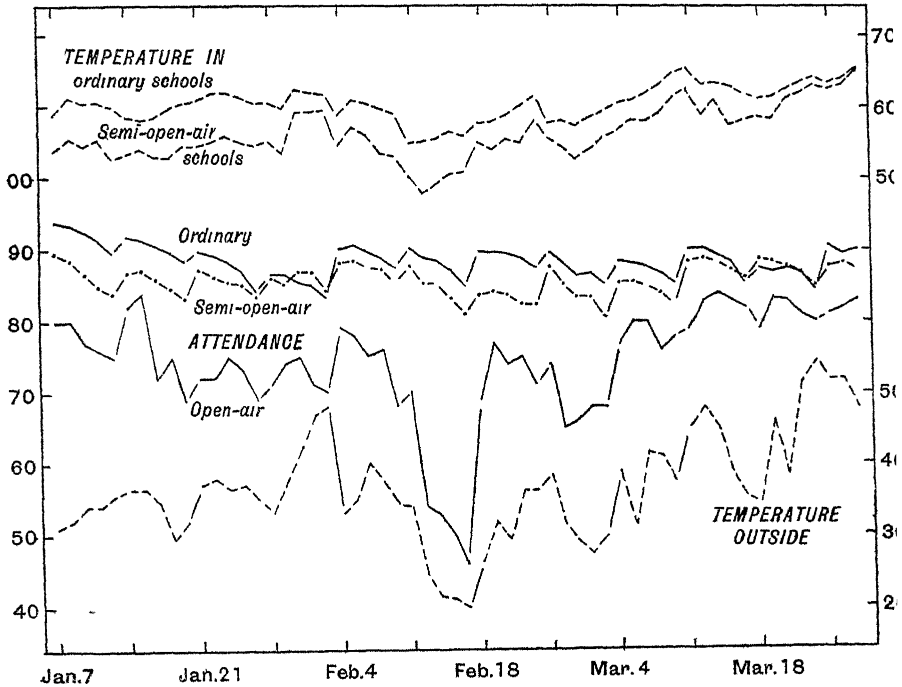

Fig. 26.—Mean daily attendance and temperature at various types of school.

that they indicate an attendance of 70 to 80 per cent. of the children during January, when the temperature (as recorded at the Meteorological Station, Kew) averaged about 35° F. With the advent of the very cold spell of weather in February the attendance fell extraordinarily. It will be seen from the figure that on February 11th, at a temperature of 34°, the attendance was 70 per cent. Next day, when the temperature had fallen to 24·5°, the attendance fell to 54 per cent., and three days later, when the temperature was 20°, it fell to 46 per cent The sudden fall of attendance between February 11th and 12th was observed at all three schools, the attendance figures being 88, 66 and 57 per cent. on February 11th, and 78, 47 and 37 per cent. respectively on February 12th. Now a sudden burst of cold weather cannot provoke an immediate increase of sickness, but acts gradually, if it acts at all, so there can be no doubt that the sudden increase of absenteeism of the open-air children was due to the parents fearing the effect of the weather on their offspring, and keeping them at home. The slighter fall of temperature experienced between February 25th and 26th caused a similar, though less marked, increase of absenteeism, and it will be seen from the figure that throughout the three months there was a fairly close correspondence between temperature and attendance.

The results obtained at the Derbyshire schools were naturally much less striking, but they are in agreement with those obtained at the open-air schools. The attendance data and temperature data at five semi-open-air schools were averaged, and are plotted in the upper part of the figure. For comparison purposes, the corresponding data at six ordinary schools are likewise plotted. These schools were the warmest of those investigated by us, and they averaged a temperature of 60·0° during the three months. It will be seen from the figure that the attendance was fairly steady throughout, and showed no tendency to fall during the very cold weather of February. Presumably this was because the class room temperature was always kept at 55° or more, for at the semi-open-air schools, where the temperature during February was under 55° and sometimes under 50°, the attendance showed a distinct fall. In the last three weeks of March, however, when the temperature in the semi-open-air schools rose to 60°, the attendance was as good as at the ordinary schools. It seems probable, therefore, that the children attending these semi-open-air schools were to some extent kept away from school during the very cold weather, quite apart from any question of sickness. Such withdrawals from school may have been due solely to the initiative of the parents, or have been to some extent prompted by the children complaining of the cold class rooms.

It will have been noted that our data show that the children attending unheated open-air schools had a considerably greater absenteeism rate than the children at ordinary schools, but this was due in part, and perhaps altogether, to their being debilitated children who were not physically fit enough to attend ordinary schools. At the London school previously mentioned a certain number of the debilitated children were kept in a warm panel-heated room, and their attendance was no better than that of the open-air children.

We ourselves did not attempt to determine what fraction of the absenteeism observed under various atmospheric conditions was due to genuine sickness, but an elaborate investigation on sickness in relation to atmospheric conditions was made in America by the New York State Commission on Ventilation (1923). The Commission enquired into the health of 5,500 school children for a period of 8 or 12 weeks in winter, and found that those who attended window-ventilated rooms kept at 59° suffered about the same amount of respiratory illness as those who attended window-ventilated rooms kept at 66·5°, though considerably less than those who attended plenum-ventilated rooms kept at 68·5°. On the other hand, children kept at 59° showed 10 to 12 per cent more absenteeism from non-respiratory illness than those kept at 66 5°, so it seems likely that some temperature between 59° and 66° might have given the best result of all.

GENERAL CONCLUSIONS.

The most important question raised in this report relates to the substitution of open-air schools for schools of the ordinary type. It is generally considered that the true open-air school, with little if any artificial heating, has an extraordinary beneficial effect on the health of sub-normal children, though we did not attempt to investigate the question ourselves. It might therefore be argued that such schools should be adopted for all children, the fit and the unfit, and that in any case the nearer we can approach to the open-air principle the better. We have seen, however that during cold weather the children attending unheated open-air schools are not able to work with more than about half the average efficiency of children attending ordinary warmed schools, and even then they need special aids to the maintenance of bodily warmth, such as extra food and extra clothing. But cannot the open-air principle be applied in some less drastic form, whereby most of its advantages are retained, without its disadvantages? We have seen that a gallant attempt in this direction has been made in the recently erected semi-open-air schools in Derbyshire and elsewhere, and we have adduced a good deal of evidence to illustrate the degree of success attained by these schemes. We have seen that if the children are to attain full efficiency at manual work such as writing and drawing, and if the absenteeism is to be maintained at its lowest figure, it is necessary that the schools be kept at a temperature not much below 60°, and in any case not below 55°, whilst the air should not have a cooling power much above 7, and in any case not above 8 or 9 It may be argued, however, that it would be better to allow a small loss of manual efficiency, and a small reduction in attendance rates, if such losses were balanced by an improvement in the health of the children. We obtained no evidence of the effect of the semi-open-air schools on health as apart from other causes of absenteeism, and it could be ascertained only by making a very laborious enquiry into the sickness of thousands of children individually, over a number of weeks, as in the investigation made by the New York State Commission on Ventilation.

There can be little doubt that the semi-open-air system, as we found it, could be improved on to some extent so as to diminish its disadvantages whilst retaining its advantages. If the heating, whether by an under-floor system or a ceiling-panel system, were increased in power, the air temperature of the rooms could be maintained at a higher level than at present without diminishing the degree of air movement induced by open doors and windows. Probably the best heating system of all, except for the expense entailed, would be to heat by a combination of the under-floor and the ceiling-panel methods. Another improvement in the semi-open-air principle depends on a very careful control of the doors and windows, so as to equalise the cooling power of the air to which the children are exposed. We saw that on a cold and windy day the children sitting near open doors might be subjected to air with a cooling power of 14, whilst those on the far side of the room were subjected to air with a cooling power of 9. Perhaps the most important principle of all is to ensure that the children never (in cold weather) sit at their work for more than an hour at a time. Morning school usually lasts for three hours, and in our experience it was customary to have only one break, so that the children often sat for 1½ or 1¾ hours on end. It is true that a period of physical drill was sometimes interposed, but it would be better to arrange the curriculum so that there was always a period of 10 minutes' exercise (in the playground or at drill) after not more than 50 or 60 minutes of sedentary work. Another improvement of the semi-open-air principle depends on the adequate nutrition of the children. An under-fed child is bound to feel the cold more than a well-fed child, and if all the children who desired it could obtain a substantial dinner at a small cost, they would need less warmth in the class room.

One serious objection to unheated open-air schools depends on the action of the parents in keeping their children at home during cold weather. This objection could be to some extent overcome by heating the schools, and the best method to adopt for this purpose would be the under-floor heating system previously described. By its means the feet of the children would be kept warm, and the artificial heat would not be wasted so much as it would be if supplied by other systems of heating. The introduction of large moderately heated ceiling panels is not to be recommended for open-air schools, as their radiation is so feeble that they warm up the surfaces they are radiating against only 1° to 3° above the surrounding air temperature. Small ceiling panels heated to a much higher temperature might be better, but they have not yet been tried, so far as we are aware. Hot-water pipes, hot-water radiators, anthracite stoves, etc., are of very little use, as they warm only the children in their immediate neighbourhood.

As regards the question of substituting under-floor heating or ceiling-panel heating for the hot-water pipe and radiator system which is employed in most schools at the present time, we saw that as compared with systems of convection heating, under-floor heating has a warming effect on persons subjected to it equivalent to raising the air temperature about 2·5°, and the ceiling-panel system a heating equivalent of about 1°. Also these systems keep the air at foot level warmer than at head level. They distribute the heat more evenly to the occupants of a room that hot-water pipes and radiators, and the apparatus does not take up valuable floor space. They are much more suitable for class rooms with glazed swing doors on two sides than hot-water pipes and radiators.

When comparing under-floor heating and panel heating, it should be realised that ceiling-panel heating is almost wholly radiant in character, whilst that from the floor is largely effected by convection. Griffiths and Davis (1922) found that of the heat loss from a warm metal plate (3 ft. to 4 ft. across) suspended horizontally in mid-air, only 31 per cent. was in the form of radiation. The remaining heat loss was due to convection currents of warm air which ascended from the plate.

Other arguments in favour of ceiling heating are adduced in a previous report (No. 46), and without wishing to dogmatise, we are inclined to think that it is preferable to floor heating for most purposes, though not for open-air schools. Neither system is free from defect unless it embraces a small amount of hot-water radiator or pipe heating in addition. We saw that the down draughts from the huge north light window in the new type of school were to some extent counteracted by the 3½ in. hot water pipe running below it, and in panel-heated rooms small hot water radiators or pipes ought to be installed under each large window, in order to neutralise down draughts.

Is the system of under-floor heating suitable for factories? In factories where much of the floor surface is covered by machinery and other articles it would certainly be unsatisfactory as it would be ineffective, and even if there were only a moderate amount of machinery the system would not be suitable if the machinery were of a heavy nature. In rooms where most of the floor was exposed and the machinery—if any—was light, the system would doubtless prove successful, and especially so in workrooms with big doors which were often opened to the outside air, for the admission of material or removal of products. It is very difficult to maintain an adequate temperature in such rooms, and they are specially liable to draughts at foot level, so a warm floor would be most welcome.

The system of semi-open-air ventilation would not be suitable for most industries, as occasional gusts of wind, usually dust-laden, are inevitable when the doors are open, and they might seriously interfere with the industrial processes.

SUMMARY.

School rooms with the whole of the floor heated to a temperature of 63° to 76° F., and with glazed swing doors (which could be fastened back in pairs) on two sides, were compared with school rooms of the ordinary type, and with a room heated by a stove. The influence of the system on the skin temperature of the face, hands and feet was explored by means of a Moll thermopile. Series of observations were made at cooling powers of 6·8, 8·3 and 10·1, and it was found that a floor-heated room kept the skin temperatures of the subjects 1° to 5° warmer than the stove room. It was calculated that at equal cooling powers the stove room felt 2·5° cooler than the floor-heated room, but this may have been due to the direct effects of conduction from the floor, which was 17° cooler in the stove room

School rooms heated by ceiling panels (at a temperature of 112°) were found to keep the skin temperature 1° warmer, on an average, than a room warmed by convected air heating, and it was calculated that at equal cooling powers the convected air room felt 1·3° cooler than the panel-heated room. In other words, a slightly lower cooling power is consistent with comfort in panel-heated rooms.

The effect of hand temperature on manual dexterity was estimated by means of a chain-assembling test, which we performed at 20-minute intervals. After three hours in air at a cooling power of 10·1 (which we felt to be " much too cold "), our hand temperature fell to 70°, and there was a loss of 12 per cent. in speed of performance. A repetition of the experiment on three boys indicated a similar loss of dexterity.

The effect of atmospheric conditions on the hand temperature of 175 children attending semi-open-air schools, panel-heated schools and ordinary schools, was systematically investigated, and it was found that this temperature varied in correspondence with the cooling power of the air. At a cooling power of 14·4, 87 per cent. of the children had a hand temperature below 70°, which we consider to be the lowest limit compatible with efficiency in performing the school curriculum, whilst at cooling powers of 9·0 and 7·2 respectively 40 and 18 per cent. of them were below our limit. The hand temperature of the children was no higher than that of the investigators, in spite of their acclimatisation.

Observations on the hand temperature of 117 children attending three practically unheated open-air schools showed that at two of them the temperatures were about 5° higher than those shown by children in artificially heated schools at equal cooling powers Probably this was due to the fact that the children were specially fed, were warmly clothed, and they sat at work for short periods only, alternating with periods of physical exercise. By means of canvas blinds the cooling power of the air at open-air schools can be reduced to less than half that experienced in unprotected sheds. Nevertheless, the efficiency of the children, in very cold weather, is only about half that of children in heated schools.

The absenteeism of the 6,312 children attending 26 schools was ascertained for a three-year period. The absenteeism was lowest (7·6 per cent.) at ordinary schools with good cross ventilation, and highest (10·2 per cent) at badly ventilated ordinary schools, whilst at floor-heated semi-open-air schools it was 8·4 per cent.

The class room temperature was recorded twice daily, and an analysis of 13,329 readings, made at semi-open-air schools during the months of November to March, showed that on 40 per cent. of all occasions the temperature was below 55°, and on 7 per cent. below 50°. An analysis of the 26,533 readings made at ordinary schools showed that 24 and 5 per cent. of them respectively were below the temperature limits mentioned.

Absenteeism is considerably influenced by temperature, for the mean absenteeism between November and March was 8·9 per cent. in schools kept at 63·4°, 11·1 per cent. in those kept at 58·5°, and 11·6 per cent. in those at 55·7°. At unheated open-air schools the absenteeism was tremendously influenced by temperature, and during a very cold spell of weather only half the children attended. This absenteeism was not due to ill health, but to the restraining action of the parents.

In conclusion, we wish to offer our cordial thanks to the education authorities controlling the schools visited, and to the staff of the schools. We are especially under obligation to the Derbyshire authorities.

REFERENCES.

(1) CAMPBELL, J. A., HARGOOD-ASH, D. AND HILL, L. (1921): "The Effect of Cooling Power of the Atmosphere on Body Metabolism." *Journ. Physiol.* Vol. 55, p. 259.

(2) CAMPBELL, J A. AND ANGUS, T. C. (1928): Physiologic Reactions of Resting Subjects to Cooling Power and Effective Temperature." *Journ. Indust. Hyg.*, Vol. 10, p. 331.

(3) DOMESTIC ENGINEERING (1929): "Cold Schools," p. 91.

(4) GRIFFITHS, E. AND DAVIS, A H (1922): "The Transmission of Heat by Radiation and Convection."—*Special Report No.* 9 *of Food Investigation Board.*

(5) KERR, JAMES (1926): "The Fundamentals of School Health." London.

(6) KUNKEL (1889): Ztschr. f. Biol. Vol 25, p. 55.

(7) MEDICAL OFFICER (1926): "Open-air Education at Nottingham." p. 237.

(8) REPORT OF NEW YORK STATE COMMISSION ON VENTILATION (1923).

(9) VERNON, H. M., BEDFORD, T. AND WARNER, C. G. (1926): "A Physiological Study of the Ventilation and Heating in Certain Factories."—*Report No.* 35 *of Indust. Fatigue Res. Board.*

(10) VERNON, H. M., VERNON, M. D. AND LORRAIN-SMITH, I. (1928): "A Physiological Investigation of the Radiant Heating in various Buildings."—*Report No.* 46 *of Indust Fatigue Res. Board.*

(11) VERNON, H. M. (1928): "Methods of Heating and Ventilating Schools, and their Influence on Health"—*Domestic Engineering*, p. 201: also *Proc. Inst. Heating and Vent. Eng.*, Vol. 27, p. 146.

(12) WIDDOWS, G. H. (1921): The Builder, p. 706.

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NOTE.—Most of the reports in the following list deal exclusively with the industries under which they are placed. In certain instances, however, reports have been prepared on some general subject, but yet make sufficient reference to a particular industry to justify inclusion under the appropriate heading. These reports are distinguished by an *.

A —MINING INDUSTRY.

No. 39.—The Relation of Atmospheric Conditions to the Working Capacity and Accident Rates of Miners.

No. 51.—A Study of Absenteeism in a Group of Ten Collieries

B —METAL AND ENGINEERING INDUSTRIES.

No. 1 —The Influence of Hours of Work and of Ventilation on Output in Tinplate Manufacture

No. 2.—The Output of Women Workers in Relation to Hours of Work in Shell-making

No. 3.—A Study of Improved Methods in an Iron Foundry.

No. 5.—Fatigue and Efficiency in the Iron and Steel Industry.

†No. 6.—The Speed of Adaptation to Altered Hours of Work.

No. 15.—Motion Study in Metal Polishing

C.—TEXTILE INDUSTRIES.

No. 7.—Individual Differences in Output in the Cotton Industry.

No. 8.—Some Observations on Bobbing Winding.

No. 9.—A Study of Output in Silk Weaving during the Winter Months.

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† A short account of the principal practical conclusions reached up to 1924 will be found in Report No. 27 (Results of Investigations in Certain Industries) *see* p. 30.

No. 17.—An Analysis of the Individual Differences in the Output of Silk-Weavers.
No. 20.—A Study of Efficiency in Fine Linen Weaving
No. 21.—Atmospheric Conditions in Cotton Weaving.
No. 23 —Variations in Efficiency in Cotton Weaving.
No. 37.—Fan Ventilation in a Weaving Shed.
No. 40.—The Effect of Eyestrain on the Output of Linkers in the Hosiery Industry
No. 48.—Artificial Humidification in the Cotton Weaving Industry. Its Effect upon the Sickness Rates of Weaving Operatives.
*No. 49.—On the Relief of Eyestrain amongst Persons Performing very Fine Work.

D.—BOOT AND SHOE INDUSTRY.

No. 10.—Preliminary Notes on the Boot and Shoe Industry.
No. 11.—Preliminary Notes on Atmospheric Conditions in Boot and Shoe Factories
*No 25.—Two Contributions to the Study of Rest Pauses in Industry
*No. 26.—On the Extent and Effects of Variety in Repetitive Work
*No. 35 —A Physiological Study of the Ventilation and Heating in Certain Factories

E.—POTTERY INDUSTRY

No. 18.—Two Investigations in Potters' Shops.

F.—LAUNDRY INDUSTRY.

No. 22.—Some Studies in the Laundry Trade.
*No. 36.—On the Design of Machinery in Relation to the Operator.

G.—GLASS INDUSTRY.

No. 24.—A Comparison of Different Shift Systems in the Glass Trade.

H.—LETTERPRESS PRINTING INDUSTRY

*No 16 —Three Studies in Vocational Selection
*No. 26.—On the Extent and Effects of Variety on Repetitive Work.
The Relation between Illumination and Efficiency in Fine Work (Typesetting by Hand).
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I.—LEATHER-MAKING INDUSTRY.

*No. 36.—On the Design of Machinery in Relation to the Operator.

J.—LIGHT REPETITION WORK.

No 14.—Time and Motion Study.
No. 25.—Two contributions to the Study of Rest Pauses in Industry.
No. 26.—On the Extent and Effects of Variety in Reeptitive Work.
No. 30.—An Experimental Investigation into Repetitive Work.
No. 32 —Studies in Repetitive Work with special reference to Rest Pauses.
No. 52.—The Comparative Effects of Variety and Uniformity in Work.
No. 56.—The Effects of Monotony in Work. (A Preliminary Inquiry).

K.—MUSCULAR WORK.

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No. 41.—Rest Pauses in Heavy and Moderately Heavy Industrial Work.
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L.—GENERAL AND MISCELLANEOUS.

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CATHCART, E. P. (1928): *The Human Factor in Industry.* London.

CATHCART, E. P., BEDALE, E. M., and MCCALLUM, G. (1923): Studies in Muscle Activity.—I The Static Effect.—*J. Physiol.*, **57,** 3 & 4.

CRIPPS, L. D., GREENWOOD, M., and NEWBOLD, E. M. (1923): A Biometric Study of the Inter-relations of Vital Capacity, Stature Stem Length and Weight in a Sample of Healthy Male Adults.—*Biometrika*, **14,** 3 & 4.

CULPIN, M. (1928): A Study of the Incidence of the Minor Psychoses—their Clinical and Industrial Importance.—*Proc. Roy. Soc. Med.*, **21,** 419. (*Sect. Psychiat*, p. 13) and *Lancet*, 4th Feb., 1928.

CULPIN, M. and SMITH, M. (1928): Sickness Absenteeism: a preliminary study.—*Brit. M. J.* 21st July, 1928.

DICKINSON, S. (1928): The Dynamics of Bicycle Pedalling.—*Proc. Roy. Soc.* B. **103,** 225.

FARMER, E. (1922): Time and Motion Study.—*J. Ind. Hyg.*, **4,** 5.

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FRASER, J. A. (1924): The Vocational Selection and Training of Operatives for the Weaving Industry.—*J. Nat. Inst. Ind. Psych.*, **2,** 2.

FRASER, J. A. (1927): The Value of Stoppage Analysis with special reference to Weaving.—*J. Nat. Inst. Ind. Psych.*, **3,** 8.

FRASER, J. A. (1929): The Machine and the Worker.—*J. Nat. Inst. Ind. Psychol.* **4,** 7.

GAW, F. (1923): The Use of Performance Tests and Mechanical Tests in Vocational Guidance.—*J. Nat. Inst. Ind. Psych.*, **1,** 8.

GREENWOOD, M., and NEWBOLD, E. M. (1923): On the Estimation of Metabolism from Determinations of Carbon Dioxide Production and on the Estimation of External Work from the Respiratory Metabolism.—*J. Hyg.*, **21,** 4.

HAMBLY, W. D., and McSWINEY, B. A. (1922): The U-tube Manometer Test with relation to Muscular Exercise.—*Proc. Physiol. Soc.*, Oct. 21, 1922.

HAMBLY, W. D., PEMBREY, M. S., and WARNER, E. C. (1925): The Physical Fitness of Men assessed by various Methods.—*Guy's Hosp. Rep.*, Oct., 1925.

HEWITT, E. M., and BEDALE, E. M. (1923): A Study of the Comparative Physiological Costs of Different Methods of Weight Carrying by Women.—*Ann. Rep. of the Chief Inspector of Factories for* 1922.

HILL, A. V. (1927): *Muscular Movement in Man.* New York.

HILL, A. V. (1927): *Living Machinery.* London.

HILL, A. V., LONG, C. N. H., and LUPTON, H. (1924): Muscular Exercise, Lactic Acid and the Supply and Utilisation of Oxygen.—*Proc. Roy. Soc.*, B. **96,** 438; **97,** 84; **97,** 155.

HILL, A. V., and LUPTON, H. (1923): Muscular Exercise, Lactic Acid, and the Supply and Utilisation of Oxygen.—*Quart. J. Med.*, **16,** 62

HILL, L., VERNON, H. M., and HARGOOD-ASH, D. (1922): The Kata-Thermometer as a Measure of Ventilation.—*Proc. Roy. Soc.*, B. **93,** 198.

HUGHES, D. E. R (1928): A Comparative Study of Unemployed and Employed boys.—*Sociol. Rev.* **20.,** 4.

JAMES, H. E O., and THOULESS, R. H. (1926): A Note on the Effect of Polarisation in Psycho-Galvanic Experiments.—*Brit. J. Psych*, **17,** 1.

LANGDON, J. N. and YATES, E. M. (1928): Transfer of Training in Manual Dexterity.—*Memoirs of Manchester Literary and Philosophical Society*, January.

LANGDON, J. N. and YATES, E. M. (1928): An Experimental Investigation into Transfer of Training in Skilled Performances.—*Brit. J. Psychol.*, **18,** 4.

LUPTON, H. (1922): Relation between External Work and Time Occupied in a Single Muscular Contraction.—*J. Physiol.*, **57,** 1 & 2.

LUPTON, H. (1923): Exercise and Oxygen.—*Med. School Gaz.*, **2,** 3.

LUPTON, H. (1923): An Analysis of the Effects of Speed on the Mechanical Efficiency of Human Muscular Movement.—*J. Physiol.*, **57,** 6.

MUSCIO, B. (1920) : Fluctuations in Mental Efficiency.—*Brit. J. Psych.*, **10,** 4.

MUSCIO, B. (1921) : Is a Fatigue Test Possible ?—*Brit. J. Psych.*, **12,** 1.

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MUSCIO, B., and SOWTON, S. M. (1923) : Vocational Tests and Typewriting —*Brit. J. Psych.*, **13,** 4.

NEWBOLD, E. M. (1923) : Note on Dr. Burnside's Paper on Errors of Observation.—*Biometrika,* **15,** 3 & 4.

PEAR, T. H. (1927) : Repetitive Work.—*Dictionary of Industrial Administration.*

PEAR, T. H. (1927) : Work, Temperament and Fatigue.—*Rep. Internal Ass. for Study of Relations and Conditions in Industry.* (Baveno), 1927.

PEAR, T. H., (1927) : Recent Studies of Skilled Performance with reference to Transfer of Training.—*Nature,* 18th Jan.

PEAR, T. H., LANGDON, J. N. and YATES, E. M. (1928) : The Nature of Manual Dexterity and its Relation to Vocational Training.—*Nature,* 12th May, 1928.

PEAR, T. H., LANGDON. J. N. and YATES, E. M. (1928) : Transfer of Training and Transference.—*New Era,* June, 1928.

PEAR, T. H. (1928) : *Fitness for Work,* London.

PEAR. T. H (1928) : The Nature of Skill (Presidential Address to the Psychology Section of the British Association, Glasgow.)—*J. Inst. Ind. Psychol* , **4,** 193, and Abstr. *Nature* 8th Sept., 1928.

PEMBREY, M. S., and OTHERS (1922) : Tests for Physical Fitness.—Part I.—*Guy's Hospital Reports,* Oct., 1921. Part II.—*Ibid.*, Oct., 1922.

RUSHER, E. A. (1922) : The Statistics of Industrial Morbidity in Great Britain.—*J. Roy. Stat. Soc.*, **85,** 1.

SARGENT, R. M. (1926) : The Relation between Oxygen Requirement and Speed in Running.—*Proc. Roy. Soc. B.*, Vol **100,** 1926.

SMITH, MAY (1923) : Practical Problems of Industrial Life.—*Ind. Welfare,* **5,** 58.

SMITH, MAY (1923) : The Laundry Trade.—*Laundry Record,* **33,** 388.

SMITH, MAY (1926) : Industrial Psychology.—*Article in Encyclopædia Britannica (XIIth Edition).*

SMITH, M. (1928) : The Worker of the Machine.—*Trans. Machinery Users' Association.* (1927–8.)

SMITH, M. (1928) : Sickness Records —*Welfare Work,* Sept., 1928.

SMITH, M. (1928) : Some Medico-psychological Problems in Industry.—*J. Neurol, and Psychopathol.* Oct., 1928.

STURT, M. (1922) : A Comparison of Speed with Accuracy in the Learning Process.—*Brit. J. Psych.*, **12,** 3.

VERNON, H. M. (1921) : The Influence of Atmospheric Conditions on Industrial Efficiency.—*J. State Med.*, **29,** 353.

VERNON, H. M. (1921) : The Influence of Fatigue on Health and Longevity. —*J. Ind. Hyg.*, **3,** 3.

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VERNON, H. M. (1923) : Atmospheric Conditions in Potters' Shops and the Efficiency of Various Types of Drying Stoves.—*Trans. Ceramic Soc.*, 22, p. 70.

Vernon, H. M. (1923) : The Causation of Industrial Accidents.—*J. Ind. Hyg.*, **5,** 1.

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Vernon, H. M. (1925) : Can Laboratory Experiments on Output throw Light on Problems of Industrial Fatigue ?—*Brit. J. Psych.*, **15,** 4.

Vernon, H. M. (1925) : The Kata-Thermometer as an Indicator of Radiant Heat.—*J. Nat. Inst. Ind. Psych.*, **2,** 198.

Vernon, H. M. (1925) : The Work of the Tin-Plate Doubler.—*J. Nat. Inst. Ind. Psych.*, **2,** 373.

Vernon, H. M. (1926) : Is Effective Temperature or Cooling Power the Better Index of Comfort ?—*J. Ind. Hyg.*, **8,** 392.

Vernon, H. M. (1927) : The Elimination of Fatigue caused by Extremes of Temperature, Humidity and Dust.—*Rep. Internat. Ass. for Study of Human Relations and Conditions in Industry.* (Baveno), 1927.

Vernon, H. M. (1927) : Ventilation in relation to Health.—*J. State Med.*, **34,** 683.

Vernon, H. M. (1927) : The Wet Kata-thermometer as an Index of the Suitability of Atmospheric Conditions for Heavy Work.—*J. Indust. Hyg.*, **9,** 287.

Vernon, H. M., and others (1926): Methods of Investigating Ventilation and its Effects.—*Med. Res. Council Spec. Rep Series No.* 100.

Vernon, H. M., and Bedford, T. (1927) : The Ventilation and Heating of Factories.—*J. Indust. Hyg.*, **9.** 51.

Vernon, H. M, and Vernon, M. D. (1927) : The Physical and Physiological Effects of Radiant Heating by the Panel System.—*Proc. Physiol. Soc., J. Physiol.*, **64,** 1.

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Vernon, H. M , Bedford, T. and Warner, C. G. (1928) : Absenteeism in Coal Miners.—*J. Indust. Hyg.*, **11,** 3.

Vernon, H. M. and Vernon, M. D. (1928) : The Physical and Physiological Effects of Panel Heating.—*Domestic Engineering.* **48,** 101

Vernon, M. D. (1926) : On Certain Effects of Long Spells of Repetitive Work.—*Brit. J. Psych.*, **16,** 3.

Warner, E. C., and Hambly, W. D. (1925) : An Investigation into the Physiological Basis of the U-tube Manometer Test.—*Guy's Hosp. Rep.*, July, 1925.

Weston, H. C. (1927) : The Relation between Illumination and Efficiency in Fine Processes, with special reference to the Lighting of Printing Works.—*Illum. Engineer*, **20,** 221.

WESTON, H. C. (1927): Light and Vision in Industry.—*Rep. Internat. Ass. for Study of Human Relations and Conditions in Industry* (Baveno), 1927.

WILSON, D. R. (1921): Some Effects of Environment on Efficiency and Safety.—*J. Roy. San. Inst.*, **42,** 3.

WILSON, D. R. (1921): The Work of the Industrial Fatigue Research Board, and its Applications to Industry.—*J. Roy. Soc. Arts,* **70,** 3660

WILSON, D. R. (1923): On Some Recent Contributions to the Study of Industrial Fatigue.—*J. Roy. Stat. Soc.*, **86,** 4.

WILSON, D. R. (1923): International Co-operation in the Study of Industrial Psychology and Physiology—*International Labour Office, Studies and Reports, Sec. F., No.* 9.

WILSON, D. R. (1924): Some Observations on Industrial Lighting.—*J. Ind. Hyg.*, **5,** 10.

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WILSON, D. R (1929) Fatigue Research and its Application in the Factory.—*Report of Tenth Annual Conference on Industrial Welfare*

WILSON, D. R. (1929): De quelques recherches récentes entreprises en Grande-Bretagne sur le facteur individuel dans les causes d'accidents.—*Rev de la Science du Travail,* **1,** 3

WYATT, S. (1925): The Effect of Atmospheric Conditions on Health and Efficiency (with special reference to the Cotton Industry).—*J. Ind Hyg*, **7,** 7.

WYATT, S. (1927): An Experimental Study of a Repetitive Process.—*Brit. J. Psych.*, **17,** 3.

WYATT, S. (1927): Machine Speeds and Output.—*J. Nat. Inst. Indust. Psych.*, **3,** 8.

WYATT, S (1928) · Causes of Irritation in Industry.—*Empire Review,* Oct., 1928

WYATT, S., and WESTON, H. C. (1920): A Fatigue Test under Industrial Conditions.—*Brit. J. Psych.*, **10,** 4.

YATES, E M. (1928) · Experimental Work upon Transfer of Training—*Report of British Association.* Glasgow, p. 607 (Abstr.).

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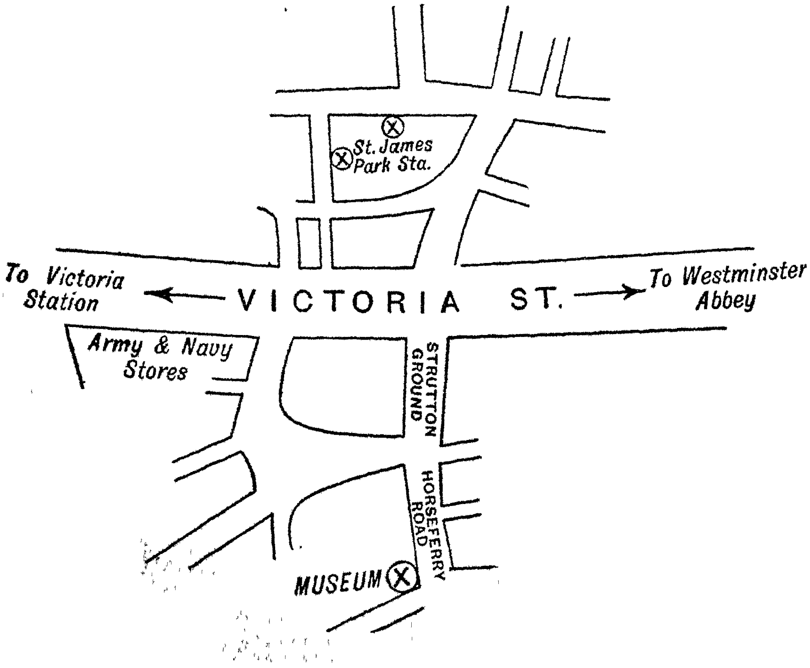

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Report No. 59.

MEDICAL RESEARCH COUNCIL.

INDUSTRIAL HEALTH RESEARCH BOARD.

Sickness amongst Operatives in Lancashire Cotton Spinning Mills

(with special reference to the Cardroom).

By A. BRADFORD HILL, D.Sc., Ph.D.

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SICKNESS AMONGST OPERATIVES IN LANCASHIRE COTTON SPINNING MILLS

(with special reference to workers in the Cardroom).

INTRODUCTORY SUMMARY.

In a previous report dealing with sickness statistics* it was pointed out that such investigations inevitably lead to reports that are somewhat elaborate and not easy to follow. They are necessarily made up of large numbers of statistical tables and of a discussion both of the figures contained in them and of the somewhat intricate analysis by which they have been reached. On the other hand, in the opinion of the Industrial Health Research Board, all these data must be presented in full, not only as proof of the conclusions reached and for the critical consideration of any persons who are closely interested, but also because these figures may have an interest to the scientific or social worker quite apart from their bearing on the particular industrial problem under review. At the same time there are undoubtedly some persons who are interested only in the particular problem investigated, but who have neither the time nor the requisite knowledge to study an elaborate and technical report. In the previous instance referred to (Report No. 54) the Board came to the conclusion that it would be of assistance to such readers if the report was prefaced by a simple and short outline of the method of inquiry adopted and the results reached by it. It has been thought wise to repeat the procedure in the present report, and this introductory summary has been prepared for that purpose.

The problem under investigation is not a new one. For many years complaints have been made by the representatives of cotton cardroom operatives in Lancashire that these workers suffer acutely from respiratory diseases, as a result of the environment in which they have to work. These operatives are occupied with processes involved in cleaning the raw cotton, preliminary to spinning. During these cleansing processes it is asserted that a certain amount of dust and fibre is thrown into the air, some of which the operatives unavoidably inhale. In addition, in the years prior to the war a considerable amount of dust was thrown into the atmosphere while the carding machines which extract the dirt from the cotton were themselves cleaned and re-sharpened—a process known as 'stripping and grinding.' In more recent

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*An Investigation into the Sickness Experience of Printers by A. Bradford Hill. *Industrial Fatigue Research Board, Report* No. 54, 1929.

years mechanical methods have been installed to remove the dust generated during stripping (by means of locally applied exhaust ventilation). The operatives believe that these improved methods have *not* solved the whole problem, but that dust and floating fibre are evolved to an extent which is injurious to health in the *carding process* (i.e. cleaning the cotton) which is continuous, as distinct from that produced during *stripping and grinding* (i.e. cleaning and re-sharpening the carding machines) which are carried out periodically during the working day In 1927, the Home Secretary (then Sir William Joynson-Hicks) appointed a Departmental Committee to examine the question, with the following terms of reference : To enquire and report :—

(1) whether, and if so to what extent, dust in cardrooms in the cotton industry is a cause of ill-health or disease among cardroom operatives,

(2) if so what is the nature of such ill-health or disease,

(3) how the sickness rates among cardroom operatives compare in these respects with those of the general population in the same locality,

(4) what are the constituents (if any) in the dust which are particularly responsible, and

(5) what remedies can be proposed.

Acting upon Term (3) the Departmental Committee asked the Industrial Health Research Board to carry out a statistical investigation of the sickness rates of cardroom operatives. This the Industrial Health Research Board agreed to do with one amendment. They pointed out that information concerning the general population in the same locality was not available and could not easily be secured. The Departmental Committee, therefore, agreed that the cardroom workers should be compared with other workers in the Lancashire spinning mills instead of with the general population.

Information concerning the sickness experience of various workers in the spinning mills was gathered for the five years 1923 to 1927 from the records of the Amalgamated Association of Card, Blowing and Ring-room Operatives (from the Approved Society Section administering, subject to Government control and audit, the National Health Insurance Acts*).

Of the men three main groups were formed :—

(1) Strippers and Grinders and other Cardroom Workers—exposed according to belief to more dust than any of the other operatives.

---

*To which was added a small amount of information relating to females from the Amalgamated Association of Operative Spinners and the Amalgamated Weavers' Association. To the officials of these three Societies the Board are greatly indebted for the help so readily given.

(2) Blowing-room hands and other preparatory workers—also engaged in cleaning the raw material; exposed to dust but not, according to belief, to the same extent as group (1).

(3) Cop Packers and Warehousemen and Ring-room Workers—engaged in processes after the cleaning has been completed; exposed to relatively little dust.

These workers were first compared with respect to the amount of sickness they suffered, in the five years under review, from all kinds of illness taken together. The strippers and grinders, etc., it was found (see Table A), had slightly less sickness than the other two groups to begin with—at ages 16–19—showing that they suffer from no initial disadvantage After age 30, on the other hand, they experienced distinctly more sickness than the workers in the ring room and warehouse, their days of sickness being 23 per cent. higher than the rate for ring-room and warehouse workers at ages 30–39, 30 per cent. higher at ages 40–49, 83 per cent. higher at ages 50–59 and 24 per cent higher at ages 60–69. In comparison with the blowing-room workers the strippers and grinders, etc., did not show this excess of illness after age 30.

The diseases from which the workers suffer were next divided up into two groups, non-respiratory illnesses and respiratory illnesses*. It was found then that the excess of sickness from all causes of illness experienced by the strippers and grinders and other cardroom workers in comparison with the ring-room and warehouse workers, was due nearly entirely to the high rates experienced by the cardroom operatives from *respiratory* causes (see Table B). From non-respiratory causes the cardroom workers do not differ very much from the ring-room and warehouse operatives; both groups lose about the same amount of working-time from diseases of such types (except in the one age-group 50–59 which may be due to a random fluctuation in the rates which are based upon somewhat small numbers). From respiratory causes the two groups differ remarkably. Up to age 30 no striking difference is seen, *but from age 30 to 59 the cardroom workers suffer over three times as much from these causes of sickness as do the ring-room and warehouse workers and at ages 60–69 at least twice as much.* Compared with the blowing-room workers, who are also exposed to dust, no such large and consistent differences are found.

It is shown in the Report that this excess of lost-time due to respiratory diseases amongst the cardroom workers is not the result of abnormally long periods of illness suffered by these workers, but is due to the fact that they make an excessive number of claims ascribed to these respiratory forms of illness. There are amongst them more men who have to make claims for benefit because of respiratory illness, and also more men who have to make repeated claims because of such illness.

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*Respiratory causes were taken as bronchitis, bronchial catarrh, asthma, emphysema, congestion of the lungs, and pneumonia. All other diseases were taken as non-respiratory (including, for reasons given in the report, pulmonary tuberculosis).

Turning to the women workers, again three occupational groups were examined:—(1) cardroom workers, not in close contact with the carding engines, but exposed to whatever dust may be blown over from these machines to the side of the room in which these women work; (2) ring-spinners and allied workers and (3) winders, reelers and allied workers; neither of these groups is exposed to any large amount of dust. The last group is not an entirely satisfactory one for comparative purposes and figures for it are therefore not included in this summary. The amount of time lost from all causes of sickness amongst cardroom workers and ring-spinners is shown in Table C. (for married and single women separately since the sickness experience of these groups is shown in National Health Insurance statistics to differ widely). The cardroom workers, it will be seen, in both groups, married and single, have less sickness than the ring spinners up to age 40. At ages 40–49 the two occupational groups have approximately the same rates, while in the final age group 50–69, the cardroom workers show an excess of time lost. When this sickness is divided up into non-respiratory causes and respiratory causes (Table D) the women in the cardroom, as well as the men, are found to have some excess of the respiratory causes, amongst single women from age 25 onwards and amongst married women from age 40. On the other hand, the excess is nothing like as large as that associated with the male operatives. The men in the cardroom showed rates from respiratory diseases, after age 30, two or three times as high as those of the warehousemen and ring-room workers; the women in the cardroom have respiratory rates more than one-and-a-half times as high as the rates of the ring-spinners (that is for single women aged 25 to 49, for married women aged 40 to 69).

These higher rates experienced by the cardroom workers of both sexes from this particular group of respiratory diseases cannot easily be explained by any other factors except working environment. On the other hand, as has already been pointed out, since 1912, when localized exhaust ventilation for stripping was being introduced, conditions in the cardroom have been materially altered. The point of obvious importance (which led to this inquiry) is whether present day conditions are such as to cause any excess of respiratory disease, as the operatives' representatives believe, or whether the excess found at the older ages is due only to the very dusty conditions in which these older operatives once worked. There is no evidence of an excess of respiratory illness amongst the younger workers who have only worked under the modern conditions (except perhaps, in the higher rates of the single women aged 25–29). On the other hand, this is not conclusive that modern conditions do not cause respiratory illness since it may be that some years' exposure is necessary before the effect of the environment will be shown in absence from work due to illness (it must be remembered, too, that the numbers of men exposed to risk at the earlier ages are small so that their rates may be unreliable).

If this is true, that some years' exposure to dust *is* necessary to produce respiratory illness of the type found to be excessive amongst these older workers, then *sickness statistics* such as are here set out, cannot prove whether modern conditions are detrimental to health or not. For at present there is no body of workers who have worked only under the modern conditions for a considerable number of years. If prolonged exposure is a factor, then ten to fifteen years must elapse before there will exist such a population of operatives who have been exposed to modern conditions for sufficiently long for its effect upon their health to be seen in sickness statistics.

It seems evident that conditions in the cardroom before localized exhaust ventilation for stripping was introduced were distinctly unfavourable to health, both men and women being affected. Such extreme conditions no longer exist and it is to be hoped that the injurious effect upon health has changed with the change of environment. In the absence of positive evidence that this is so, the reduction of the operatives' exposure to dust and fibre, to the maximum extent possible, is obviously desirable.

TABLE A.

Male Operatives.—1923–27.—*The Sickness (i.e. first* 26 *weeks of illness) experienced from* ALL CAUSES *of illness.*

Age Group.	Strippers and Grinders and other Cardroom Workers.	Workers in the Ring-room and Warehouse.	Blowing-room and other preparatory workers and workers in both card- and blowing-room.	Strippers' and Grinders' rates as percentage of	
				Workers in the Ring-room and Warehouse.	Blowing-room workers, etc.
	Number of Days of Sickness per person-year of exposure *				
16–19	4·41	4·89	4·71	*90*	*94*
20–29	4·50	4·42	3·26	*102*	*138*
30–39	4·17	3·38	5·15	*123*	*81*
40–49	5·84	4·49	6 30	*130*	*93*
50–59	10·61	5·81	10·48	*183*	*101*
60–69	20·51	16·48	16·32	*124*	*126*
Total number of persons exposed	3,165	1,661	1,115		

* The exposed to risk has to be given in this form since it is made up of so many persons exposed for the whole period and so many (entries and exits) exposed for only a part. The addition of these two gives "person-years"; in other words, 100 person-years of exposure are the equivalent of 100 persons exposed for one year, though actually they are composed of more than 100 persons exposed for varying durations, some for a whole year and some for less.

TABLE B.

Male Operatives.—1923–27.—*The Sickness* (*i e. first* 26 *weeks of illness*) *experienced from* (1) NON-RESPIRATORY DISEASES and (2) RESPIRATORY DISEASES.

Number of Days of Sickness per person-year of exposure.

Age Group.	Strippers and Grinders and other cardroom workers.		Workers in the Ring-room and warehouse.		Blowing-room Workers and other preparatory workers.		Strippers' and Grinders' Rates as percentage of			
							Workers in the Ring-room and Warehouse.		Blowing-room Workers, etc.	
	Non-Respiratory Causes	Respiratory Causes.	Non-Respiratory Causes.	Respiratory Causes.	Non-Respiratory Causes	Respiratory Causes	Non-Respiratory Causes.	Respiratory Causes.	Non-Respiratory Causes.	Respiratory Causes.
16–19	3·90	0·51	4·39	0·49	4·21	0·50	*89*	*104*	*93*	*102*
20–29	3·88	0·62	3·75	0·67	2·87	0·39	*103*	*93*	*135*	*159*
30–39	3·23	0·94	3·09	0·28	3·86	1·29	*105*	*336*	*84*	*73*
40–49	4·07	1·77	3·98	0·51	4·52	1·78	*102*	*347*	*90*	*99*
50–59	6·01	4·60	4·45	1·37	6·60	3·88	*135*	*336*	*91*	*119*
60–69	11·27	9·24	12·04	4·44	11·90	4·42	*94*	*208*	*95*	*209*

TABLE C.

Female Operatives.—1923–27.—The Sickness (i.e first 26 weeks of illness) experienced from ALL CAUSES *of illness.*

Age Group.	Single and Widowed Women.			Married Women.		
	Cardroom workers.	Ring Spinners.	Cardroom Workers' rates as percentage of spinners.	Cardroom workers.	Ring Spinners.	Cardroom Workers' rates as percentage of spinners.
	No. of Days of Sickness per person-year of exposure.			No. of Days of Sickness per person-year of exposure.		
16–19 ..	6·47	6·80	95	—	—	—
20–24 ..	7·55	8·73	86	17·92	22·35	80
25–29 ..	6·67	8·22	81	14·60	17·07	86
30–39 ..	8·06	8·87	91	14·19	16·39	87
40–49 ..	10·24	10·39	99	14·45	14·28	101
50–69 ..	17·25	12·46	138	19·75	15·04	131
Total number of persons exposed.	13,251	3,423		9,237	2,386	

TABLE D.

Female Operatives.—1923–27 —*The Sickness* (*i e. first* 26 *weeks of illness*) *experienced from* (1) NON-RESPIRATORY DISEASES *and* (2) RESPIRATORY DISEASES.

Number of Days of Sickness per person-year of exposure.

Age Group.	Cardroom Workers.		Ring Spinners.		Cardroom Workers' rates as percentage of ring spinners	
	Non-Respiratory Causes.	Respiratory Causes	Non-Respiratory Causes.	Respiratory Causes.	Non-Respiratory Causes	Respiratory Causes.
		Single and Widowed Women				
16–19 ..	5·95	0·52	6·22	0·57	96	91
20–24 ..	6·94	0·61	8·04	0·69	86	88
25–29 .	6·00	0·68	7·80	0·42	77	162
30–39 ..	7·05	1·01	8·24	0·63	86	160
40–49 ..	8·44	1·80	9·51	0·88	89	205
50–69 ..	12·59	4·66	8·96	3·51	141	133
		Married Women				
20–24 ..	16·72	1·20	20·68	1·67	81	72
25–29	13·53	1·07	16·02	1·05	84	102
30–39 ..	12·87	1·32	14·94	1·45	86	91
40–49 ..	12·08	2·37	12·90	1·38	94	172
50–69 ..	14·35	5·40	12·15	2·88	118	188

SICKNESS AMONGST OPERATIVES IN LANCASHIRE COTTON SPINNING MILLS

(with special reference to workers in the cardroom)

BY

A. BRADFORD HILL, Ph.D., D.Sc.

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Introduction.

For a considerable number of years complaints have been made by the representatives of cotton cardroom operatives in Lancashire that these workers suffer acutely from respiratory diseases, as a result of the environment in which they have to work. In 1927 the Home Secretary (then Sir William Joynson-Hicks) appointed a Departmental Committee to examine the question, with the following terms of reference: To inquire and report :—

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(2) if so what is the nature of such ill-health or disease,

(3) how the sickness rates among cardroom operatives compare in these respects with those of the general population in the same locality,

(4) what are the constituents (if any) in the dust which are particularly responsible, and

(5) what remedies can be proposed.

Acting upon Term (3) the Departmental Committee asked the Industrial Health Research Board to carry out a statistical investigation of the sickness rates of cardroom operatives. The Industrial Health Research Board agreed to do so (the results are presented in this report) with one modification. It was pointed out that no sickness rates existed for the general population resident in the Lancashire towns involved. To obtain such figures by special inquiry would be virtually impossible. It would involve the taking, by some means, of a local census of all workers insured under the National Health Insurance Acts ; the Approved Society to which each belonged would have to be ascertained ; and finally the sickness history for each of these workers would have to be secured over a specified period from each of the Approved Societies involved. This would undoubtedly mean approaching at least one hundred to two hundred Societies, very few of which would have any direct interest in the investigation. Quite apart from these difficulties in organizing such a form of inquiry it was suggested that " other operatives in spinning mills " would make a better comparative group than the " general population." In comparing sickness rates it is of very considerable importance to keep in view the amount of unemployment and the wage rates of the work-people, since sickness incidence *may* be affected by either. It is not difficult to allow for these factors if the comparison is confined to different groups of cotton operatives. It is far more intricate if the scores of industries to which the general population belongs all have to be examined. In addition, in comparing the cardroom workers with operatives in other parts of the mill the environment of each group can be studied. With the general population a very large number of industries would, possibly, have to be examined.

If the comparison could be absolutely controlled, as in a laboratory experiment, obviously the ideal would be a group of cardroom workers on the one hand, working in their normal environment, and on the other a group of workers doing precisely the same task but in an atmosphere completely free from dust and fibre. Such a comparison as this is, of course, out of the question, but it was considered that, failing this, other cotton operatives most nearly supply an adequate "control" group. It is not difficult to obtain sickness statistics for these workers since large numbers of them belong to the one or two Approved Societies attached to the Trade Unions.

The Departmental Committee agreed to this modification of the terms of reference so that the sickness rates of the cardroom operatives, discussed in this report, are examined in comparison with the rates of other operatives in spinning mills (in the same localities) and not with the rates of the general population.

The Occupations and Environmental Conditions of the Spinning Mill.

Before presenting the various data collected it may assist the reader unacquainted with the trade processes if a brief account is given of the operations carried out in a spinning mill. Such an account will necessarily be very elementary, many technicalities and points of detail are purposely excluded. The object is only to give the reader a broad idea of the processes and of the environment.

When the raw cotton is imported into this country it is in bales, densely compressed by hydraulic power. It is very far from clean. The "ginning" process carried out at the plantations fails to remove all the seeds from the cotton, and in addition it contains a considerable amount of dust from the soil in which the cotton plant was grown. The first procedures are, therefore, concerned with the opening out of the cotton into a loose state and the cleaning of it. The bales are opened in the *bale room* or *cotton room* by male operatives, usually termed *cotton mixers.* These workers take handfuls of cotton from a number of bales and throw them in a mixture on to a travelling lattice. The cotton is drawn by this lattice into a machine called the bale-breaker, the construction of which varies, while in some mills the cotton is thrown direct into this machine without the intervention of a lattice. Within the machine the compressed lumps of cotton are torn apart by a roller fitted with spikes, and the cotton is passed on in a looser and more open condition. From the bale-breaker it is, in some mills passed directly to the "opener," in others it is discharged into the *mixing room* or *cotton chamber.* This sometimes consists of a number of small rooms with boarded walls, but with no front, while in other cases the enclosures are complete,—large store chambers they might be termed. From the cotton chamber it is taken to the "opener." This machine may be situated in the *blowing* or *scutching room.* Loose masses of cotton from the cotton chamber are put into the opener, and are there separated still more thoroughly than was done by the bale-breaker and are further cleaned. The cotton is drawn through the machine by a strong current of air and finally emerges in the form of a "lap" —a flat sheet about three to four feet broad and about half an inch thick which is wound into a roll as it leaves the machine (the final result resembling a very large roll of "cotton wool" or wadding).

Further mixing and cleaning are carried out in this room by the "scutcher." Several laps placed upon the top of one another are drawn into the scutcher together. The cotton is still further separated and cleaned, and again emerges in the form of a lap— a lap of more even proportions and more average quality than each of those which entered the machine. The men employed in supervising these machines are termed *blowing-room operatives,* while a *blowing-room major* is in charge. The final laps are taken off the machines and weighed by *scutcher tenters* who may be men or women, boys or girls. From the blowing-room the laps are taken by *lap carriers* to the *cardroom.* In the carding machine the cotton is separated and cleaned for the last time and at the same time the cotton fibres are drawn out into parallel lines This is done by means of wire " cards." The machine consists of a large cylinder covered with " card-clothing "—cloth in which have been set hundreds of fine pointed steel wires (about 300 per sq. in.). Above this cylinder are a number of narrow iron bars called " flats," similarly covered with card-clothing. These flats are fastened together in an endless chain and pass slowly along the surface of the cylinder which is revolving in the same direction, but very much more rapidly. The cotton is torn from the lap by a coarse-toothed roller and passes between the cylinder and the flats. The wires separate the fibres from one another and draw them into a parallel position on the cylinder. Short fibres, dust and dirt are retained mainly by the flats and card cylinder clothing. The cleaned cotton fibres are taken from the main cylinder automatically by means of a smaller cylinder known as a " doffer " and they are removed from this by a rapidly oscillating comb, finally leaving the machine in the form of a " sliver," or narrow tape, which is coiled round and round as it emerges and passes into a can some three feet in depth. As the endless chain of flats turns over, the short fibres and dirt are combed out of the wires by an oscillating comb and fall on the front casing of the machine. During the carding process a certain amount of dust is continually given off at different points of the machine. It is necessary that a process of cleaning the wires of the cylinder and doffer, known as *stripping* and a reshaping and sharpening of the wires, known as *grinding,* be carried out at suitable intervals. Previous to about the year 1910, stripping was carried out by revolving the cylinder slowly and applying to it a rapidly revolving power-driven cylindrical wire brush. Much of the dust and fibre caught in the wires was thrown out into the air so that the men engaged in the work were enveloped in a cloud of dust. The stripping procedure is carried out two or three times a day for each carding machine. In grinding, the machine is first stripped with additional care and then a revolving cylinder covered with emery, and known as a grinding roller, is applied to the card. This cylinder has a traversing motion across the card cylinder and thus grinds down the wires to a true surface. The men employed in this work are known as *strippers and grinders.*

A report upon these methods and the resulting environmental conditions (which will be referred to again later) was made to the Chief Inspector of Factories in 1908, and led to some means being installed for the removal of the dust produced *during stripping* at its point of origin. In the majority of mills one of two methods was adopted. The stripping brush had a cover placed over it connected with an exhaust system which draws away the dust as it is produced ; or the cylinder and doffer cylinder are cleaned by a vacuum stripper, the nozzles of which pass to and fro across the cylinder and doffer and suck out the dust and fibre. Accordingly, since about 1910, the amount of dust liberated in the cardroom has been very materially reduced.

In addition to the strippers and grinders there are employed in this part of the cardroom the *carder* who is in charge of all the processes carried on in the cardroom, and the *under-carder* who is his deputy ; *lap carriers* who bring the laps from the blowing-room to the cardroom and *card or can tenters*, usually women or girls, who remove the full cans of slivers and replace them by empty ones.

One side of the cardroom is taken up with these carding machines ; on the other (or infrequently in another room altogether) are the draw-frames and speed-frames which carry out the next processes. If the cotton is intended for fine spinning the sliver is first put through a variety of machines known as the sliver lap machine, the ribbon lap machine and the comber, the main object of which is to remove the still remaining short fibres and to secure a more uniform sliver. The object of the draw-frame is to combine a number of slivers into one so as to obtain finally a thread of uniform thickness and strength over its whole length. For instance six or eight slivers are passed through the machine and emerge as one, in which the fibres have been drawn quite parallel to one another. Six of the resulting slivers are treated in the same way on a second draw-frame and the process may be repeated a third time.

In charge of all these machines is the carder who has one or two under-carders below him, and below the latter are the strippers and grinders and " girl tenters " on the draw frames and speed frames. The final slivers from the last draw-frame pass to the adjacent speed-frames of which there may be several— " slubbing," " intermediate," and " roving " frames. On the slubbing frame the sliver is drawn out into a much finer strand (it becomes a " roving ") and is wound upon a bobbin, a slight twist being given to it in the process. On the intermediate frame two rovings are drawn out and wound together, to eliminate any remaining inequalities, and a further twist is imparted. On the roving frames the same processes are repeated once more. Looking after these machines—piecing broken ends, replacing full bobbins by empty ones—are girls known by various names, *e.g.*, *slubbing tenters*, *intermediate tenters*, *roving tenters*, or in a general way as *speed-frame tenters* and their juvenile assistants, usually known as *back tenters*. These workers are, it should be noted, exposed to some extent to whatever dust is produced by the carding, stripping and grinding processes. Being normally in the same room some of the dust and fibre permeate the atmosphere which they breathe, being driven about by the rapidly moving bands and machinery. In the cardroom are also *bobbin carriers* who take the bobbins to the lift, where the *hoistman* receives them and takes them to the *spinning rooms.* Spinning may either take the form of mule-spinning or of ring-spinning. The difference in process between the two is not of any importance here. In either case the operation, broadly speaking, is the drawing out of the roving into thread and imparting to this thread the required amount of twist. The only important difference as far as this inquiry is concerned is that mule-spinning is generally carried out by men and boys—*spinners or mule minders, piecers and creelers*—while ring-spinning is a woman's occupation. There are a certain number of men in the ring-room—the head of the room or the *ring overlooker, oilers* and *banders,* and *ring-room jobbers,* while there may be boys as doffers (or takers off) or bobbin carriers—but the actual spinners are women In both kinds of spinning rooms the atmosphere may be slightly humidified artificially (by injection of steam or atomised water), and, relative to other parts of the mill, the temperature must be kept high. The final spun thread, known generally as " yarn " passes to the *warehouse* where it is packed for sale by *cop packers.* Other cops of spun thread go from the spinning room to the *winding and warping department.* Here the thread is first wound on to warper's bobbins and then on to a " beam," ready to form the warp in the weaving shed, or it may be reeled into hanks. Women are largely concerned in these processes as *winders, beamers* and *reelers.* The beams go finally to the *sizing room* where they are smoothed and strengthened by being passed through a boiling paste.

A spinning mill is thus divided roughly into the following departments :—

(1) The bale room or cotton room.
(2) The cotton chamber or mixing room.
(3) The blowing or scutching room.
(4) The cardroom :
    (*a*) Carding section.
    (*b*) Draw-frame and speed-frame section.
(5) The mule or ring spinning room.
(6) The winding, warping, reeling and sizing department.
(7) The warehouse.

The bale room, the cotton chamber, the blowing-room and the carding section of the cardroom are all occupied with the opening, mixing and cleansing of the raw cotton. In all of them the operative works to some extent in an atmosphere that contains floating fibre and dust, which, according to assertion, reach their maximum in the cardroom and to which the strippers and grinders are the workers most exposed. In the draw-frame section of the cardroom the cleansing process has come to an end, but the workers at the frames are exposed, in most mills, to whatever dust may be blown across from the carding machines.

The spinning rooms are relatively free from dust and contain considerably less floating fibre, but they are in some mills artificially humidified and kept at a fairly high temperature.

The warehouse and the winding, warping and reeling departments are also relatively free from the fibre and dust liberated in the cleansing processes. In the warehouse the air is generally kept moist by some means of humidification—injection of steam or atomised water or a water surface on the floor.

The Problem to be Investigated and its History.

As mentioned in the introduction to this report the origin of this investigation is to be found in the concern of the officials of the Trade Union to which Cardroom workers belong over the health of their members. It is asserted, and has been asserted for a considerable number of years, that the dusty atmosphere in which the cardroom operatives work—and most especially the strippers and grinders—affects their health, more particularly by making them liable to or inducing bronchitic complaints.

As evidence the Amalgamated Association of Card and Blowing-room Operatives published in 1908 a pamphlet entitled " Copies of Certificates given by Medical Men shewing that the Inhalation of Dust in Cardrooms impairs the Health of the Operatives employed in them."

This pamphlet is made up of medical reports certifying that certain workers have been suffering (in most cases) from bronchitis and asthma and that in the opinion of the doctor (again in most cases) their physical condition and ill-health are the results of working in the dusty atmosphere of the cardroom. For example :

> " I hereby certify that Mr. ——— ——— ———— (34 years of age), suffers from Chronic Bronchitis and Emphysema of some years' duration, after 19 years' work in the Cardroom of a Cotton Mill, and that in my opinion the disease is due largely to the dust amongst which he has worked."
>
> (The names of the patients and of the qualified medical practitioners signing the certificates are given in the original report.)

Such complaints led the Chief Inspector of Factories in 1908 to appoint Dr. (now Professor) E. L. Collis to make some investigation of the condition of workers in the Cardroom Professor Collis examined 126 men employed as strippers and grinders in Blackburn mills, and concluded that 93 of them, or 74 per cent., had had their health affected by the inhalation of dust. Describing the condition of the sufferer he says " the man loses flesh and any fresh colour he may have had. Consequently he becomes thin in the face and body. As the chest trouble develops into a typical form of asthma, the action of the diaphragm becomes less and less effective, until the only action of this great respiratory muscle is to fix the lower ribs; at the same time the superior intercostal muscles are being brought more and more into use, and the extraordinary muscles of respiration are more and more called into play to carry on the ordinary act of breathing. The sternum becomes more prominent and the chest becomes barrel-shaped. Meanwhile, the extra tax thrown on the lungs leads to some degree of emphysema. There is little or no sputum produced, and what little there is is expectorated with difficulty. It is not infrequently stained with blood, but I only found doubtful physical signs of phthisis in one case who so complained The practice of opening the bedroom window at night, even in winter (an unusual habit with these men), indicates the difficulty in breathing which is experienced by them at this stage."* Professor Collis did not suggest that the dust given off in the ordinary processes of carding, *i.e.*, in cleaning the lap of cotton, was injurious, but urged that that produced in stripping, *i.e.*, cleaning the wires of the carding engine after some use, must be removed by exhaust ventilation. His conclusion was that " there is no doubt that if this principle of ventilation is carried out in all the mills, that grinders' and strippers' asthma will cease to exist except among the irreparably damaged old hands." As has already been mentioned stripping with localized exhaust ventilation or by vacuum has become the practice in all mills; such methods had been agreed to by the industry by the end of 1912 and were thereafter gradually adopted.† The operatives believe that these improved methods have *not* solved the whole problem but that dust and floating fibre are evolved in the carding process, as distinct from those of stripping and grinding, to an extent which is injurious to health. Before turning to the results of the present investigation, designed to test, if possible, this belief, it will be of value to examine the evidence offered by the occupational death rates published by the Registrar-General.

Occupational Death Rates in the Cotton Industry.

In the Registrar-General's reports occupational death rates are given for men only. In the latest report—that relating to deaths in 1921–23—six occupational groups are given: cotton blow-room operatives; cotton card and frame (not spinning frame) tenters; cotton strippers and grinders and cardroom jobbers; cotton spinners and piecers; cotton doublers, winders, warpers, beamers, etc.; and cotton weavers. Using the information given for these groups Table I has been compiled.

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* Annual Report of the Chief Inspector of Factories for 1908, pp. 203–205.

† Vide the Departmental Committee's report for further evidence on this point.

Occupational Death Rates, 1921–23. *Cotton Operatives.*

Turning to Table I. it will be seen that from *all causes of death less respiratory diseases* strippers and grinders have somewhat lower rates than any of the other groups up to the age group 45–55, (excluding the age group 16–20 which is based upon very few deaths). From 45 to 65 years of age they die at approximately the same rate, and after age 65 they die somewhat faster. When compared with spinners and piecers the difference in death rates from diseases of the *respiratory system* is very distinct. For 1921–23 the stripper's and grinder's death rates from this group of diseases after age 35 are 1·50, 5·15, 15·97, 28·49 and 103·03, while the corresponding rates for the spinners and piecers are only 1·08, 2·20, 6·10, 15·55 and 42·07—somewhere about half the height. The blowing-room operatives both from respiratory diseases and from all other causes die faster than the strippers and grinders up till middle age but at a slower rate after that. Cotton card and frame tenters have, except in early life, higher rates than the spinners both from respiratory diseases and from all other causes. Though their general death rates are as a rule higher than those of the strippers and grinders, their death rates from respiratory diseases are somewhat lower.

Occupational Death Rates, 1921–23. *Cotton Operatives and all Workers in England and Wales.*

As well as comparing these different groups of workers together it is possible to compare them with all workers (occupied and retired) in England and Wales. This is done in Table II using the Registrar-General's Comparative Mortality Figures for 1921–23. The comparative mortality figure is a standardized death rate, a device for making comparable two or more death rates when the populations concerned have differing age constitutions. Mortality being closely connected with age, allowance has to be made for this factor. Obviously an occupation employing old persons will have a higher death rate than a similar one employing young persons. Unless the age difference is taken into account the difference in mortality conveys nothing. Table II thus states that the comparative mortality figure from all causes of death for all occupied and retired civilian males is 1,000; if the death rates at ages actually found to prevail amongst strippers and grinders are applied to this standard population their comparative mortality figure from all causes of death is found to be 1,396. These two figures are directly comparable, the differences in the age constitution of the population of strippers and grinders and the population of all males having been eliminated.*

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* For definition, choice of standard population and method employed *vide* the Decennial Supplement, Registrar-General of England and Wales 1921, Part II.

TABLE I.—*The deaths and death-rates of Cotton Operatives in* 1921–23. (*Figures compiled from the Registrar-General's Decennial Supplement, Part II*, 1921).

Age.	16—	20—	25—	35—	45—	55—	65—	70 and up.
		Population *						
Strippers and grinders**	756	1,818	5,076	3,999	2,721	1,440	351	165
Blowing-room operatives	840	1,131	1,995	1,929	1,866	1,245	318	171
Cotton card and frame tenters	1,992	1,206	2,604	3,087	2,472	1,251	426	306
Cotton spinners and piecers	27,378	18,801	27,603	23,061	18,174	11,154	2,379	2,163
Deaths from all causes less bronchitis, pneumonia, chronic interstitial pneumonia, and other diseases of the respiratory system.								
Strippers and grinders	3	3	10	17	33	46	33	33
Blowing-room operatives	4	5	7	18	24	35	19	29
Cotton card and frame tenters	2	3	14	23	37	45	20	62
Cotton spinners and piecers	68	72	96	126	203	361	162	381
Deaths from bronchitis, pneumonia, chronic interstitial pneumonia and other diseases of the respiratory system								
Strippers and grinders	—	1	4	6	14	23	10	17
Blowing-room operatives	—	2	2	3	10	12	4	9
Cotton card and frame tenters	—	—	2	7	4	16	10	18
Cotton spinners and piecers	9	9	12	25	40	68	37	91
Death-rate per 1,000 from all causes of death less bronchitis, pneumonia, chronic interstitial pneumonia and other diseases of the respiratory system.								
Strippers and grinders	3·97	1·65	1·97	4·25	12·13	31·94	94·02	200·00
Blowing-room operatives	4·76	4·42	3·51	9·33	12·86	28·11	59·75	169·59
Cotton card and frame tenters	1·00	2·49	5·38	7·45	14·97	35 97	46 95	202·61
Cotton spinners and piecers	2·48	3·83	3·48	5·46	11·17	32 37	68·10	176·14
Death-rate per 1,000 from bronchitis, pneumonia, chronic interstitial pneumonia, and other diseases of the respiratory system.								
Strippers and grinders	—	·55	·79	1·50	5·15	15·97	28·49	103·03
Blowing-room operatives	—	1·77	1·00	1·56	5·36	9·64	12·58	52·63
Cotton card and frame tenters	—	—	·77	2·27	1·62	12·79	23·47	58·82
Cotton spinners and piecers	·33	·48	·43	1·08	2·20	6·10	15·55	42·07

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* Census population in 1921 multiplied by 3 to correspond with the 3 years of deaths.

** Groups 55, 51, 53 and 56 in Registrar-General's Supplement. *The occupational groups and titles are those adopted by the Registrar-General.*

Table II shows that all the groups of cotton operatives have higher comparative mortalities from all causes of death than do all occupied and retired males in England and Wales. The spinners show the least disadvantage, and the blowing-room operatives and the card and frame tenters the greatest. From respiratory tuberculosis both strippers and grinders and blowing-room operatives die at a lower rate than do all males; spinners and card and frame tenters are approximately on a par with all males. For diseases of the respiratory system the rates bear the following relationships to that for all males: strippers and grinders, nearly 3 times as high; blowing-room operatives, nearly two and a half times as high; card and frame tenters, twice as high; spinners and piecers, one and a quarter times as high. For bronchitis the relationships of the death rates are: strippers and grinders, over five and a half times as high as all males; blowing-room operatives, three times as high; card and frame tenters and spinners, approximately one and a half times as high. From pneumonia the strippers and grinders have a rate about one and a half times as high as the rate for all males, while the rates for blowing-room and card and frame tenters are over twice as high, and spinners show only a slight excess. The general conclusion is that from diseases of the respiratory system grouped together and from bronchitis separately strippers and grinders have a very heavy mortality in comparison with the general male population (occupied and retired) of England and Wales, that blowing-room operatives also suffer heavily from these causes of death but less severely than the strippers and grinders, that card and frame tenters and spinners and piecers show some excess but, especially for the spinners, the difference is far less distinct than it is for the first two occupational groups.

TABLE II.—*Standardized mortality (comparative mortality figures) of Males aged* 20–65 *years employed in the Cotton Industry, from all causes and from causes connected with the respiratory system, compared with that of all Occupied and Retired civilian males taken as* 1,000. 1921–23.*

	All Causes (including Respiratory diseases).	Respiratory Tuberculosis.	Diseases of the Respiratory System.†	Bronchitis.	Pneumonia.
All occupied and retired civilian males.. ..	1,000	1,000	1,000	1,000	1,000
Strippers and grinders and cardroom jobbers	1,396	796	2,856	5,579	1,593
Blow-room operatives ..	1,516	750	2,432	3,020	2,278
Card and frame (not spinning frame) tenters	1,601	1,057	2,071	1,647	2,181
Spinners and piecers ..	1,248	1,072	1,273	1,431	1,180

* Figures from the Registrar-General's Decennial Supplement. 1921. Part II. Table D. p. cxxii–iii. R.-G.'s occupational groupings.

† Bronchitis, pneumonia, chronic interstitial pneumonia, and other diseases of the respiratory system (excluding tuberculosis).

Occupational Death Rates, 1921–23. *Strippers and Grinders and all Workers in Bolton, Oldham and Rochdale.*

If the strippers and grinders be compared (as is done in Table III) not with the general population of England and Wales but with the general population of roughly the same localities no very different result is reached. In Table III strippers and grinders (as given in the Registrar-General's supplement) are compared with the population of the three county boroughs of Bolton, Oldham and Rochdale. From all causes of death less those of the respiratory system strippers and grinders have rates up to age 45 lower than those of the general population of these three towns. At ages 45–65 they have the same rate, and at

TABLE III.—*The deaths and death-rates of Strippers and Grinders compared with those of the general population of Bolton, Oldham and Rochdale.* 1921–23. (*Figures compiled from the Registrar-General's Reports*).

Age.	15—	25—	45—	65 and up.
Population.*				
Strippers and grinders	2,574	9,075	4,161	516
Bolton, Oldham and Rochdale	103,251	175,395	122,364	24,441
Deaths from all causes less bronchitis, pneumonia and other diseases of the respiratory system.				
Strippers and grinders	6	27	79	66
Bolton, Oldham and Rochdale	297	915	2,248	2,011
Deaths from bronchitis, pneumonia, and other diseases of the respiratory system.				
Strippers and grinders	1	10	37	27
Bolton, Oldham and Rochdale	50	192	526	541
Death-rate per 1,000 from all causes less bronchitis, pneumonia and other diseases of the respiratory system.				
Strippers and grinders	2·33	2·98	18·99	127·91
Bolton, Oldham and Rochdale	2·88	5·22	18·37	82·28
Death-rate per 1,000 from bronchitis, pneumonia and other diseases of the respiratory system.				
Strippers and grinders	·39	1·10	8·89	52·33
Bolton, Oldham and Rochdale	·48	1·09	4·30	22·13

* Census-population of 1921 multiplied by 3 to correspond to the three years of deaths.

ages over 65 they have a considerably higher rate. From respiratory diseases they have lower rates in early life but an excess, rising with age, in later life, so that after age 45 their death rate from these causes is over twice as high as that of the three county boroughs. It must be remembered, too, that the strippers and grinders are included in the county boroughs and contribute to their rates. If they could be deducted their excess of respiratory deaths would be still more distinct. In the final age group, 65 and over, the comparison must necessarily be a very inexact one. The mortality rate recorded depends partly upon the age distribution of persons in that group. If the average age of the persons in the towns over 65 is higher than that of the strippers and grinders (as is probable), then the position of the latter is understated.

Death Rates from Circulatory Diseases. Cotton Operatives

Before leaving this section on the death rates of cotton operatives as a whole, attention must be paid to certain factors to which the Registrar-General draws notice In the Decennial Supplement for 1921 it is stated that circulatory mortality " is a very definite feature of one very distinctive group of occupations, the textile trades . . . The textile position is still more remarkable in regard to chronic nephritis . . . With this nephritis excess, no doubt, is associated another distinctive mortality of textile workers—that from cerebral haemorrhage . . . It thus appears that the conditions of work in textile mills promote degenerative changes of the kidneys, heart, and blood vessels."*

The comparative mortality figures for these causes of death (combined) for 1921–23 are set out in Table IV for the four occupational groups under discussion, and are there compared with the similar figures, already given, for respiratory diseases and bronchitis. Amongst all the cotton operatives there is a distinct excess mortality, in comparison with all males in England and Wales, from the group of circulatory and allied diseases It is least amongst strippers and grinders and spinners, greatest amongst card and frame tenters and blowing-room operatives. On the other hand it should be noted that for strippers and grinders this excess is of far smaller dimensions than that associated with respiratory diseases and bronchitis ; for blowing-room hands it is also less but not nearly so substantially so. Card and frame tenters die slightly more from the circulatory than from the respiratory diseases, while for spinners and piecers there is very little difference. It must be remembered too that the respiratory diseases cause considerably more deaths amongst all these cotton operatives than do the circulatory diseases—in each group the number of deaths from respiratory diseases (*i.e.*, bronchitis, pneumonia, and other respiratory diseases) is about two and a half times as great as the number of deaths from these circulatory and allied causes. For strippers and grinders, whose health forms the main problem of this inquiry, the death rates of the respiratory groups certainly seem of more importance than the circulatory mortality. In some sense, however, the two forms of mortality seem to be bound up in one another since for the 164 forms of occupations in the Registrar General's report it is shown that there is a definite association between these two groups of deaths. In occupations in which the bronchitis death rate is high the circulatory death rate tends to be high too.*

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* Registrar-General of England and Wales. Decennial Supplement, 1921, Part II, p. XXXIII.

TABLE IV.—*Standardized mortality (comparative mortality figures) of Males aged* 20–65 *years, employed in the Cotton Industry, from all causes and from certain selected causes connected with the respiratory and circulatory systems, compared with that of all occupied and retired civilian males taken as* 1,000. 1921–23.†

	All Causes	Diseases of the Circulatory System and allied Causes ‡	Diseases of the Respiratory System.§	Bronchitis.
All occupied and retired civilian males	1,000	1,000	1,000	1,000
Strippers and grinders and card-room jobbers	1,396	1,566	2,856	5,579
Blow-room operatives	1,516	1,841	2,432	3,020
Card and frame (not spinning frame) tenters	1,601	2,166	2,071	1,647
Spinners and piecers	1,248	1,403	1,273	1,431

One last point must be noted with regard to these occupational death rates. In comparison with all occupied and retired males the position of the cotton operatives may be under-stated since those who are unable to work in the environment of the trade, owing possibly to ill-health acquired in it, leave it and their deaths are debited to their new occupation. Professor Collis in his report in 1908 drew attention to this factor and believed that there was a considerable efflux of workers with injured health from the cardroom into other occupations (*e g.*, corporation labourers, paper mill labourers, etc.).

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* *Vide* Registrar-General's Decennial Supplement, 1921. Part II. p. XXXIX. The correlation coefficients are bronchitis with chronic nephritis + ·380 ± ·045, bronchitis with cerebral haemorrhage + ·411 ± ·044; bronchitis with "other" (myocardial) heart disease + ·300 ± ·053.

† Figures compiled from the Registrar-General's Decennial Supplement. 1921. Part II.

‡ Includes the following headings :—Diseases of the circulatory system; diseases of the heart; valvular disease of the heart; other heart diseases; cerebral haemorrhage; chronic and acute nephritis.

§ Same causes as in Table II.

Whether the comparison between strippers and grinders and spinners understates the position it is impossible to say since there may be an elimination of the physically unfit from both groups or from only one.

The Investigation of Sickness.

The Method Employed.

In making an investigation of sickness amongst cotton operatives there was a choice of two methods

(1) Starting with specified mills a " census " of the operatives at work in them on a given date would be taken Part of the information obtained would be the code number of the Approved Society to which the operative belonged. At the end of a chosen period after the date of the " census " (for instance one year), the sickness history of each operative over this period of time would be obtained from the appropriate Approved Society. This sickness could then be related to the occupation of the operative, which would be ascertained at the census, and to the mill in which the operative worked. Some of the operatives, however, obviously would cease to work during the period of inquiry in the mills in which they were found at the date of the " census." Instead of being " exposed to risk " for the whole period they would only be exposed for some weeks or months. To take count of this it would be necessary for periodical returns to be made by the employers of all operatives definitely ceasing to be employed by them for any other reason than permanent disability. Adjustment could then be made as to the exact time each worker was " exposed " in a particular mill.

There are several disadvantages attaching to this method. Since in each cardroom there are very few strippers and grinders, to get a sufficient " exposed to risk " a very considerable number of mills would have to be selected. A large number of employers would therefore have to co-operate and the organization required for the " census " and the periodical returns of workers leaving would be somewhat substantial. A second consideration is that very many Approved Societies would have to be approached for the sickness histories, and, as with the " general population," many of these would be without any interest in the inquiry. The sickness histories would only be available at the *end* of the chosen period so that some delay would be essential before the inquiry could be completed. The period chosen could not, probably, exceed two years for this reason, and also because, unless " entries " were added, the labour movement out of the mills selected would be continually diminishing the "exposed to risk." The period of inquiry, naturally, must lie in the future whatever trade conditions may be like.

Finally the sickness history can only relate to "short" sicknesses for the following reason. The persons included in the "census" must have been *at work* at the date of the "census," for otherwise the details relating to their Approved Society could not have been obtained. Obviously then, if the period of inquiry is a year after the "census" the duration of sicknesses suffered must lie within a year. All persons suffering from prolonged sicknesses or permanently incapacitated are excluded since they could not have been employed at the time of the "census." On the other hand the sickness histories can be related to some extent to the variations in environments in the particular mills (unless the labour turnover is too great).

(2) The alternative method is to take the sickness histories over a selected period of all the members of those Approved Societies which are attached to the Trade Unions of cotton operatives, which are very largely confined in their membership to workers in cotton mills. From the point of view of National Health Insurance these societies are on exactly the same basis as any other societies Their members draw sickness benefit in the ordinary way, only after certification of their incapacity by a panel doctor.

From these Approved Societies would have to be obtained, as well as the sickness history, the exact occupation of each operative. The sickness could then be related to the various occupational categories; it could not be related to the different environments in which particular operatives were at work, for the Approved Society has, normally, no knowledge of the workplaces of its members. This is the disadvantage of the method. On the other hand no extensive organization is required; the employers are relieved of the labour of the "census" and the lists of those leaving their mills, many Approved Societies are relieved of the labour of extracting sickness histories. These histories can be obtained at once since a past period of time can be selected, and this period can be so chosen as to coincide with the best possible trade conditions. In addition a larger number of years of sickness history can be taken than is possible with the first method. Finally, the permanently and semi-permanently incapacitated are included. The advantages of this method are, thus, considerable and it was this method that was finally adopted for the investigation. At the same time further steps were taken to enable the question of differing environments to be considered.

Collection of Data.

The records were taken from three trade Approved Societies—Approved Society No. 1265, the Insurance Section of the Amalgamated Association of Card, Blowing and Ring Room

Operatives; Approved Society No. 1144, the Insurance Section of the Amalgamated Association of Operative Cotton Spinners; and Approved Society 1111, the Insurance Section of the Amalgamated Weavers' Association.

The years chosen for investigation were 1923–27 inclusive, *i.e.*, a five years' record. From the Association of Card, Blowing and Ring Room Operatives were taken particulars of every member of the insurance section, male and female, during those years, *i.e.*, every member for the whole period or for a part of the period.* The length of time that each operative was a member during those years, and the dates at which he or she became qualified for benefits, were noted and due allowance made for those who were only "exposed to risk" for some fraction, and not for the whole, of the period. A complete sickness history of each member during this period was taken from the Societies' record cards. (All this work was carried out at the offices of these Societies by clerks specially appointed by the Industrial Health Research Board for the purpose, samples of their work being checked against the original records by the investigator). The number of male members of the Association of Card, Blowing and Ring Room Operatives over this five year period was just over 8,000 and of female members approximately 30.000. Of the males it was estimated that about 3,000 would be cardroom workers, and about 5,000 "other cotton operatives." (Actually it was found that the number finally available for comparative purposes was very much smaller than this, *vide* Table V). This comparative group of other operatives it was hoped to increase by records from the Association of Operative Spinners. The Insurance Section of this Society, however, had a male membership over the five years of over 30,000. It was unnecessary to take records for the whole of this membership since the comparative group would then be unnecessarily large in comparison with the cardroom group, and the labour and cost involved would have been considerable. It was considered that a quarter of this group would be sufficient. Accordingly a random sample of one in four was decided upon. The record cards are kept by the Approved Society divided into the branches to which the members belong. (These branches are synonymous with towns since there is one branch to each town). Within the branch, cards are in order of membership number. Live and "dead" members are kept separately. The procedure agreed upon was that starting with the first card in each section every fourth card should be scrutinized and where the fourth card referred to membership during 1923–27 the particulars required were to be abstracted. Only the fourth card was ever to be taken; no substitution was to be made for it for any reason whatever, *e.g.*, lack of necessary particulars.

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* Excluding only those members who joined the society between 1923 and 1927 but never completed their qualifying period for sickness benefit.

The sample was to cover the complete membership, alive and dead. Owing, however, to an unfortunate oversight this sample miscarried and has been discarded. Before starting on the work it was not brought to the attention of the investigator that the cards of members during sickness were transferred to a "temporary" box, being returned to their normal places in the branch boxes at the end of the period of sickness, and owing to a misapprehension on the part of the clerk in charge of the work this "temporary" box was not properly sampled. The method used by the clerks was as follows: one clerk scrutinized each fourth card and extracted the membership particulars; the second clerk followed behind him and extracted the sickness particulars. If between the extraction of the membership particulars and the sickness particulars the member had fallen sick his card would have been transferred by the Society's clerks to the temporary box. In such cases the card was fetched from the temporary box and the required sickness particulars obtained. This led the clerk in charge to suppose, without referring the matter to the investigator, that he had sampled the temporary box. He overlooked the fact that the permanently disabled and persons ill throughout the time during which the sample was being taken were *always* in the temporary box, and therefore could never have had their membership or sickness particulars procured. Chronic disability was therefore very seriously understated in the sample. Short-period sickness would not be so affected, and comparison of the number of claimants to sickness benefit in the years 1925, 1926 and 1927 showed that for *all ages* the number of claimants was understated in the sample only to the extent of 4 per cent. On the other hand no test is possible to show how much the different age groups are affected—the older ages are certainly more likely to be affected than the younger ages—or to show whether the loss affects respiratory causes more or less than other causes of illness. No means of correction of the sample were possible and it has therefore been thought better to base no conclusions upon it but to rely upon the much smaller control group provided by the Association of Card, Blowing and Ring Room workers. It may be added, however, that the figures reached with the biassed sample of 8,000 lives from the Association of Operative Cotton Spinners broadly confirm the conclusions based upon this smaller control group. The bias in short-period sickness was not sufficient to nullify the very distinct differences (shown later) between the sickness experiences of the cardroom workers and the other cotton operatives in the older age groups.

Turning to the female membership, out of the some 30,000 members in the Insurance Section of the Card, Blowing and Ring Room Association it was estimated that about twenty thousand would be workers in the cardroom. This would leave a comparative group of about ten thousand (actually after certain eliminations this comparative group was about 6,500, *vide* Table XVIII). This number was further increased by the records of about 1,400 members of the Weavers' society (Oldham branch), those members being selected who worked in the warping and winding rooms, and of 179 women similarly employed and belonging to the Operative Spinners' Society.

Source of Information as to Occupations

Reelers and Winders.—For these female members of the Operative Spinners' Society and the Amalgamated Weavers' Association, the occupation *at entry into the society* was taken as the occupation during 1923–27. This occupational grouping is in error in proportion to the movement of such workers out of the cotton industry or into other sections of it. The movement out of the industry results in the occupational groups called "winders" in this investigation actually being composed of winders and members of the general population who were, at one time, winders. When their sickness rates are compared with those of the cardroom workers the change to an outside occupation does not alter their validity as a control group. Movement of winders to other parts of the mill is not of much importance unless such workers go to the cardroom. In other parts of the mill they would still form part of the comparative group. If they move to the cardroom but are here classified as winders the comparison between the two groups is weakened by this inclusion of actual cardroom workers amongst the occupational groups termed winders. Evidence of the extent to which this occurs will be given when the sickness rates of the women are presented.

Cardroom Approved Society Members.—For the members of the Card, Blowing and Ring Room Association, male and female, special means had to be taken to ascertain the precise occupation of the worker, the record on the Society's cards being only "cotton operative." For this purpose a questionnaire was drawn up with the following three questions upon it:

(1) What was your exact occupation during the years 1st January, 1923 to 31st December, 1927? If you changed your occupation during these years give both occupations and date of change.

(2) Where were you employed during 1st January, 1923 to 31st December, 1927? Give the name of each town and each mill if you were in more than one during these years and the dates at which you entered and left each mill.

(3) If you were *not* a cardroom worker during 1st January, 1923 to 31st December, 1927, were you *ever* at work in a cardroom? If so when and for how long?

A questionnaire was filled in with the name and address of each member of the Approved Society during 1923 to 1927 and through the Trade Union contribution collectors in each district one was delivered to every member still alive and still available. In the case of dead members or members with whom contact had come to an end (*e.g.*, emigrants) information was obtained from relatives or friends or from the personal knowledge of the collector or of the Approved Society's sick visitors.

Analysis of the Data.

MALES.

Occupations.

Out of a male membership of 8,165, information was obtained in these ways for 8,009 or 98 per cent. For 151 of the remaining 156 males information as to occupation *at entry into society* was used instead of occupation during 1923–27, and in only five cases was no information obtained. This use of occupation at entry will introduce some slight error in the occupational groups if there has been any labour movement amongst these 151 workers, but their number is so small compared with the total that the error can only be negligible. The occupation, place of work and other relevant information given on each form was entered upon the corresponding card giving the sickness history. The numbers found in each occupation are set out in Table V.

Certain considerations arise in the grouping of these various occupations. It must be remembered first that for results to have satisfactory reliability they must be based upon relatively large numbers ; the larger the numbers the greater the reliance that can be placed upon the results. It is useless to deal with small groups numbering only one or two hundred or less—except, on occasions, merely as confirmatory evidence of conclusions reached with larger numbers or by other methods. For this reason certain small groups must be included with a larger group, although on some grounds their treatment separately would be more satisfactory. For instance it would be of advantage to examine the sickness of the male slubbing tenters, combers and frame overlookers on one side of the cardroom separately from the strippers and grinders directly in contact with the carding machines on the other side. But, it will be seen, in the former group there were only 50 males and it would be valueless to treat these alone. They must either be excluded altogether or included in the cardroom group. For the same reason it is of no value to treat workers returned as carders and undercarders separately from strippers and grinders, and also because the former occupation is constantly recruited from the latter. The cardroom group has therefore been extended to include the first 10 occupations given in Table V and comprises in all 3,165 workers. Certain of these workers may not be employed all their time in the cardroom but only come to and fro to it at intervals ; this applies to the lap carriers, bobbin carriers and hoistmen. If any peculiar incidence of sickness is found in this cardroom group that might be ascribed to the effect of dust, it is probable that this peculiarity is diminished by the inclusion of some of these workers and would be more distinct if it had been possible to take strippers and grinders alone.

TABLE V.—*The numbers found in each occupational group amongst male members of the Card, Blowing and Ring Room Insurance Approved Society.*

Carders and undercarders	323	
Carder and stripper and grinder during 1923–27	60	
Strippers and grinders	2,167	
Cardroom jobber, worker, labourer or operative	182	
Cardroom tenters, card box tenters, can tenters (in some cases becoming stripper and grinder during 1923–27)	117	
Lap piecers and carriers (in some cases becoming stripper and grinder during 1923–27)	80	
Bobbin carriers (in some cases becoming stripper and grinder during 1923–27)	131	
Condenser minders and tenters	23	
Slubbing tenters, combers and frame overlookers	50	
Hoistmen (some of whom have worked in cardroom)	32	
		3,165
Cotton room, cotton mixing and cotton chamber workers	222	
Blowing room operatives or hands, scutchers and finishers	660	
Wastemen and waste baggers	35	
		917
Cop packers, warehousemen, conditioners and one or two roller coverers		868
Ring room jobbers, oilers and banders, spinners and piecers, bobbin carrier in ring room, doffers, and thread doublers		793
In both card and blowing room during 1923–27 or blowing room in 1923–27 and cardroom previously		198
Outside the trade or in other parts of the mill in 1923–27 but previously in the cardroom		646
Outside the trade in 1923–27 but previously in blowing room, ring room or warehouse	102	
Workers with more than one occupation in the mill during 1923–27 (excluding those who were ever in the cardroom), *e g.*, piecer and cop packer	41	
Odd jobs in mill, *e g*, labourer (undefined), time-keeper, clerk, loom oilers and sweepers	111	
In occupations outside the trade and no reference to previous work in a mill	1,183	
In Army or Navy during 1923–27	67	
On workman's compensation benefits during all or most of 1923–27	18	
On war pensions or treatment allowances	51	
Untraced	5	
		1,578
Total..		8,165

In the description previously given of the occupations and environments in a spinning mill it was noted that the earlier processes of treating the cotton (apart from the cardroom) were all involved one way or another in cleaning and mixing the raw material. In the later processes the dust has been eliminated and workers in the ring-spinning room and the warehouse are therefore in distinctly different environmental conditions from those of the blowing-room workers It is obviously of importance not to mix these " control " groups together since their environment differs so considerably, and also because the death rates show quite distinct differences between the blowing-room hands and the spinners. A further reason for differentiation is that there is believed (in the opinion of the trade representatives supervising the inquiry) to be very little interchange between occupations in the cardroom and occupations in the spinning rooms and warehouse. In these returns very few workers in the spinning rooms and warehouse stated that they had previously been in the cardroom. With the blowing room and other preparatory processes the position is quite different. There is certainly quite a considerable interchange, and it is shown in Table V that 198 workers had been at work at some time both in the cardroom and blowing room. This is probably a minimum since there is a tendency amongst the workers to use the term " cardroom " to cover all these earlier processes. For instance on some questionnaires the worker replied that his occupation was a blowing-room hand, while in reply to the question " were you *ever* at work in a cardroom " he said " yes, all my life." There is therefore a possibility that some workers who returned themselves as blowing-room hands did not reply to the final question at all since they regarded themselves as " cardroom " workers in this wider sense. Whether they had ever worked in the actual cardroom (in the true sense) would then not be known. However this may be, it is certain that the blowing-room and other early processes do not provide an absolutely reliable comparative group, for the differentiation of the cardroom worker and blowing-room worker cannot be distinct. The second group is therefore composed of these workers in the cleaning and mixing processes (exclusive of the cardroom), together with a very small group of wastemen. Operatives who have worked both in the card and blowing rooms have been treated separately to begin with, but finally amalgamated with the blowing-room group, as will be seen later. The third group comprises the warehouse workers and the workers in the ring-spinning room.

The last group that has been analysed is composed of workers who once worked in the cardroom but in 1923–27 had ceased to do so. This is a group of some importance as it should show whether there is any elimination from the cardroom of the physically disabled, and whether ill-health possibly acquired in the cardroom continues after leaving it.

One-fifth of the membership has not been utilized. The first three groups (outside the trade in 1923–27 but previously in blowing, ring room or warehouse ; workers with more than one occupation in the mill during 1923–27—excluding those ever in the cardroom; odd jobs in a spinning mill) are all of some interest but the numbers in them (102, 41, and 111) are not large enough to justify analysis, and they cannot be reasonably added to any of the larger groups. Nearly 1,200 workers were outside the cotton industry altogether in 1923–27 and had not worked previously in the cardroom. They may have worked previously in the ring room or warehouse or in any other department but this is not known. At first sight it might be thought that these workers would supply a "general population in the same localities," but for two reasons they fail to do this. The first reason is that, as has just been pointed out, many of them may be ex-mill workers and so are not clearly differentiated from the cotton industry. The second is that the bulk of this population is composed of youths under 25 years of age and the numbers in the later ages are not sufficient to be of much value. A number of youths who very likely started their working life in spinning mills and left because of unemployment, can hardly be utilized as typical of the "general population." The rejection of all the other groups (army and navy, prolonged compensation cases, war pension cases and untraced members) explains itself.

Sickness.

For examination of the sickness data there remain, after these occupational groupings, three main and two subsidiary groups. These will be entitled as follows and contain the numbers given against them.

Table VI. Occupational Groupings.

Three main groups (all members of the Card, Blowing and Ring Room Association).	
Strippers and Grinders and other Cardroom Workers	3,165
Blowing-room hands and other preparatory Workers	917
Cop Packers and Warehousemen and Ring Room Workers	1,661
Two Subsidiary Groups (all members of the Card, Blowing and Ring Room Association).	
Operatives who have worked in both Card and Blowing Rooms	198
Workers in the Cardroom who have left it for other employment	646

A preliminary analysis showed that the subsidiary group of workers who had been employed at some period of time both in the card and blowing rooms did not differ in sickness incidence materially from the blowing-room group (some of the members of which may have worked, as previously pointed out, in the card-room but omitted to state it). The number of days of sickness suffered per person-year of exposure * in each group was as follows :

Number of Days of Sickness per person-year of exposure.

Age.	Blowing-room hands and other preparatory workers.	Workers employed at some time in both card and blowing-room.
16–19	4·8	4·5
20–29	3·5	2·5
30–39	5·2	5·0
40–49	6·3	6·2
50–59	10·5	10·6
60–69	17·5	10·2

In only one age group does the difference appear to be material. At ages 60–69 the blowing-room hands have 17·5 days per person-year and the workers in both card and blowing-rooms only 10·2 days. But this latter rate is derived from only 64·5 person-years of exposure (or about thirteen or fourteen persons) and little importance can be attached to the difference. It was considered that in view of this agreement of the sickness rates and the occupational resemblance already discussed, it was justifiable to amalgamate these two groups and this has been done in the further tables.

Procedure in calculating rates and definitions of technical terms.—Before turning to the rates found some account is needed of the procedure followed in calculating them. The difference between sickness and disablement, in the technical sense of the National Health Insurance Acts, is that sickness is the first 26 weeks of illness, and disablement is illness continuing after the first 26 weeks. The first 26 weeks of illness may be either one prolonged period of incapacity or it may be reached by a series of short " linked-up " periods of sickness which are separated from one another by less than a calendar year. Under the Act any two periods of sickness separated by less than a calendar year are counted as the same sickness and both count towards the first 26 weeks of incapacity. An interval of a calendar year nullifies this linking-up process and after an interval of that length the calculation of the first 26 weeks of incapacity begins afresh. In addition there is a longer qualifying period for disablement benefit than there is for sickness. A person does not become qualified to draw disablement benefit until he has been in insurance 104 weeks and paid 104 contributions; he or she becomes qualified for sickness benefit after 26 weeks and 26 contributions. Hence the person-years of exposure to risk differ, though only materially in the first age group. For these technical reasons it is better to keep the two types of illness apart, and also because a few chronically disabled persons may contribute so much to the total incapacity of a relatively small population that they may obscure actual differences in sickness incidence

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* The exposed to risk has to be given in this form since it is made up of so many persons exposed for the whole period and so many (entries and exits) exposed for only a part. The addition of these two gives " person-years " ; in other words, 100 person-years of exposure are the equivalent of 100 persons exposed for one year, though actually they are composed of more than 100 persons exposed for varying durations, some for a whole year and some for less.

In dealing with claims it may be pointed out now that in this investigation every period of illness has been counted as a claim irrespective of whether it was "linked-up" with another period or not. Also, the whole of the sickness has been included in the calculation of the duration, *i.e.*, the first 3 days of illness which are not paid for (unless linked-up) are included here in *all* periods of sicknesses. Finally, the sickness and disablement have been calculated for each calendar year separately and then totalled for the five years. This means that one continuous claim running into two or three calendar years appears as two or three claims in the total. Unless this is done the great disadvantage of over-lapping age groups must result (*e.g.*, a person claiming at age 29 in 1923 is age 30, and, therefore, in the next age group, in 1924). Such claims naturally do not form a very large proportion of the total (except possibly in disablement).

Periods of incapacity definitely stated to come under the Workmen's Compensation Act have not been included, and no allowance has been made for them. This overestimates the exposure to risk since persons away incapacitated are continued as exposed to risk, but the error is not of any magnitude. As has already been pointed out persons drawing Workmen's Compensation for a very prolonged period have been excluded from the experience altogether, as have also cases of incapacity due to the war. The latter have no bearing on occupational risks.

Sickness and Disablement Rates of the Occupational Groups from All Causes of Illness.—In Tables VII and VIII are set out the figures for the sickness and disablement experienced from all causes of illness in the three occupational groups—the strippers and grinders and cardroom workers, the ring-room and warehouse workers and the blowing-room workers. The sickness rates (Table VII), *i.e.*, days of sickness experienced per person-year of exposure, show that the cardroom group have rates closely approximating to those of the ring-room and warehouse workers in early working life, that is from ages 16 to 30. After age 30, on the contrary, they have a distinct excess of sickness, their days of sickness per person-year being 123 per cent. of the rate for ring-room and warehouse workers at ages 30–39, 130 per cent. at ages 40–49, 183 per cent. at ages 50–59 and 124 per cent. at ages 60–69. In comparison with the blowing-room workers, on the other hand, the strippers and grinders, etc., do not show this consistent excess of illness after age 30.

Figures for disablement (long-period incapacity after the first 26 weeks of sickness) are not very satisfactory for populations as small as these. For such forms of illness a much larger exposed to risk is needed to secure stable rates. Therefore only their general indication will be referred to, and the rates for the cardroom workers will not be given as percentages of the rates for the other workers, both being liable to large random fluctuations.

Table VIII shows that for this long-period morbidity the comparison between the cardroom workers and the ring-room and warehouse workers gives broadly the same result as was found in the comparison of short-period illness. The cardroom workers have less disablement at the start of working life but suffer an appreciable excess after age 30. In this case they have, too, an excess over the blowing-room workers, an excess which was absent from the short-period sickness figures.

The origin of this excess of illness can be shown to lie, mainly, in the abnormal rates experienced by the cardroom workers, aged 30 years and over, from respiratory diseases.

Sickness and Disablement Rates from Respiratory Diseases and from all other causes less respiratory diseases.—In Tables IX and X the sickness and disablement experiences are subdivided into all causes of illness less respiratory causes and respiratory causes alone. The causes defined as respiratory are bronchitis, bronchial catarrh, asthma, emphysema, congestion of the lungs and pneumonia. In Tables IX and X are given the actual numbers exposed to risk, the days of illness suffered and the numbers of claims made. In Tables XI and XIII are given the rates based upon these figures, while in Table XII the sickness rates of the cardroom workers are expressed as percentages of the rates of the two comparative groups.

Reference to Tables XI and XII shows that from all causes of sickness less respiratory causes the cardroom workers do not differ appreciably from the ring-room and warehouse operatives either in days of sickness or in number of claims made, except in the one age group 50–59 (which may be due to a random fluctuation in the rates which are admittedly based upon somewhat small numbers). From respiratory causes they differ remarkably. Up to age 30 no striking difference is seen, but from age 30 to 59 the cardroom workers suffer *over three times as much from these causes of sickness as do the ring-room and warehouse workers and at ages* 60–69 *at least twice as much.* Their position is shown in comparison with these other cotton operatives in the ring-room and warehouse in figure (1).

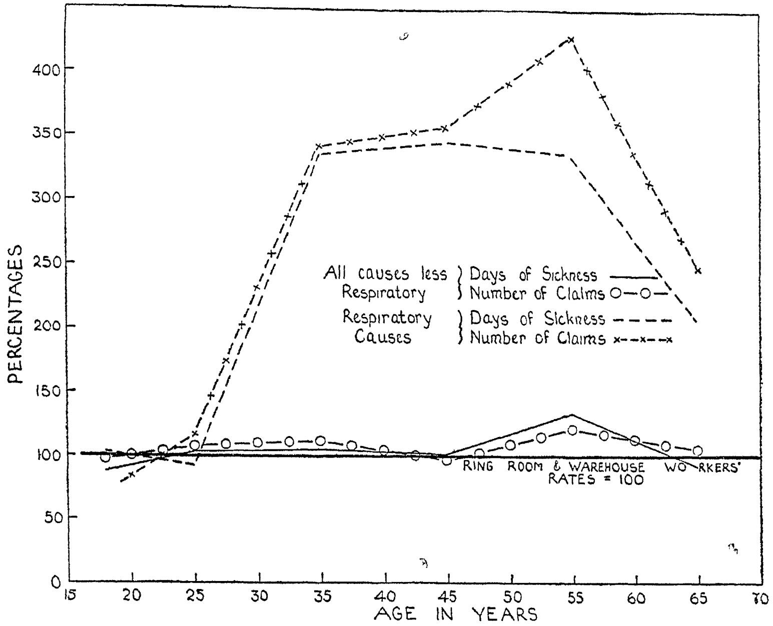

FIG. (1).

1923–27. Sickness rates found for Strippers and Grinders, MALES (days of sickness per person-year and number of claims per 100 person-years), expressed as percentages of the rates found for Male workers in the Ring Room and Warehouse.

Comparing the cardroom group with the blowing-room group (Tables XI and XII) no such abnormal discrepancy in rates is found—as would be expected, as previously pointed out, in view of the greater similarity of environment compared with the other occupational groups, and also because of the interchange of workers. From all causes of sickness less respiratory causes the cardroom workers have, taken as a whole, slightly fewer days of sickness than the blowing-room group, and in later life slightly fewer claims. The difference in neither case is very pronounced and, since the blowing-room group is relatively a small one, it is probably not significant. It is probably fair to say that from all causes of sickness less respiratory causes the two groups suffer equally.

From respiratory causes taken alone there is, similarly, no consistent difference in incidence. The cardroom operatives suffer more from these causes up to age 30, less from ages 30–39, about as much at ages 40–49, and more after age 50. Since the cardroom rates for these respiratory causes are higher than the blowing-room rates in four out of the six age groups, and roughly equivalent in the other two age groups, it is justifiable to say that the cardroom workers have a slightly higher morbidity from such causes than the blowing-room workers. The difference, obviously, is far less than the difference between cardroom workers and the ring-room and warehouse workers.

The disablement experience divided into these two morbidity cause groups is too liable to random fluctuations in the rates to allow any detailed consideration of it. In general it suggests confirmation of the conclusions reached from the more stable short-period sickness rates, the cardroom workers showing, as a whole, no such pronounced excess of illness from non-respiratory causes as they reveal from respiratory illness after age 30.

Incidence of Tuberculosis amongst the Cotton Operative groups.—In selecting the two cause groups for comparison (respiratory causes and all causes less respiratory causes) *respiratory tuberculosis* was not included with the respiratory diseases but kept in the general group. The medical members of the sub-committee supervising the inquiry were of opinion that exposure to certain dusts may cause respiratory complaints of a bronchial type but not tuberculosis. Judging by the standardized death rates (*vide* Table II) and Professor Collis's evidence (quoted on p. 12) the cardroom workers show no abnormal incidence of this complaint. As a cause of death they suffer from it somewhat less than all civilian males and less than spinners and piecers (the number of deaths upon which the standardized death rates are based is, however, not very large). Actually when the sickness and disablement rates for tuberculosis (of all forms) found in this inquiry were examined it was seen that strippers and grinders showed from ages 20 to 60 a *higher* incidence than the ring-room and warehouse workers. If these tuberculosis rates were added to the respiratory group instead of to the non-respiratory group it would have the effect of making the strippers' and grinders' excess of respiratory illness at these ages still more abnormal.

The Duration of Sickness Claims amongst the Cotton Operative groups.—It was seen that the excess of respiratory illness amongst cardroom workers, when compared with ring-room and warehouse workers, was in evidence both in the number of claims made and in the total duration of sickness suffered. It is of some interest to see whether this excess in number of days of sickness per person-year is the result only of this greater number of claims or whether it is also derived from a longer duration of each claim. The figures in answer to this question are given in Table XIV.

Comparing first strippers and grinders with ring-room and warehouse operatives, it is seen that the difference in length of claim from non-respiratory causes is very slight, and not consistent over the age groups. From respiratory causes, after the first age group (which is based upon too few claims to be reliable), they make somewhat shorter claims. Compared with the blowing-room workers the strippers and grinders show no consistent differences in claims from non-respiratory causes. From respiratory causes there is, again, a suggestion of shorter claims up to age 50.

The conclusion is that the excess of sickness of a respiratory nature amongst cardroom operatives is due to a larger *number* of claims being made, possibly of a slightly shorter average duration than those made by the control group, and *not to an abnormal average length of incapacity* suffered by strippers and grinders

TABLE VII.—*Males, 1923–27.—The* SICKNESS *experience from all causes.*

Age Group (age last birthday at beginning of year of exposure).	Strippers and Grinders and other Cardroom Workers.			Workers in the Ring-room and Warehouse.				Blowing-room and other preparatory workers and workers in both card and blowing-room.			
	Person-years of exposure to risk.	Total duration of sickness in days.	Number of days of sickness per person-year of exposure.	Person-years of exposure to risk.	Total duration of sickness in days.	Number of days of sickness per person-year of exposure	Strippers' and Grinders' rate as percentage of rate of these ring-room and warehouse workers.	Person-years of exposure to risk.	Total duration of sickness in days.	Number of days of sickness per person-year of exposure.	Strippers' and Grinders' rate as percentage of rate of these blowing-room workers.
16–19	695·5	3,069	4·41	1337·0	6,534	4·89	*90*	323·0	1,520	4·71	*94*
20–29	1944·0	8,742	4·50	1897·5	8,395	4·42	*102*	852·0	2,775	3·26	*138*
30–39	3663·5	15,284	4·17	1570·5	5,304	3·38	*123*	859·5	4,425	5·15	*81*
40–49	3865·0	22,575	5·84	1363·0	6,123	4·49	*130*	1223·0	7,699	6·30	*93*
50–59	2351·0	24,939	10·61	610·0	3,545	5·81	*183*	1039·5	10,896	10·48	*101*
60–69	961·5	19,716	20·51	183·5	3,024	16·48	*124*	389·0	6,350	16·32	*126*
Total number of *persons* exposed	3,165			1,661				1,115			

TABLE VIII.—*Males,* 1923–27.—*The* DISABLEMENT *experience from all causes.*

Age Group (age last birthday at beginning of year of exposure).	Strippers and Grinders and other Cardroom Workers.			Workers in Ring-room and Warehouse.			Blowing-room and other preparatory workers and workers in both Card and Blowing-room.		
	Person-years of exposure to risk.	Total duration of disablement in days.	Number of days of disablement per person-year of exposure.	Person-years of exposure to risk.	Total duration of disablement in days.	Number of days of disablement per person-year of exposure.	Person-years of exposure to risk.	Total duration of disablement in days.	Number of days of disablement per person-year of exposure
16–19	440·0	8	·02	813·0	1,244	1·53	213·5	33	·15
20–29	1,917·5	3,204	1·67	1,883·5	6,152	3·27	848·5	1,988	2·34
30–39	3,634·0	8,373	2·30	1,562·5	1,056	·68	844·0	64	·08
40–49	3,836·5	23,494	6·12	1,351·5	3,649	2·70	1,214·5	4,235	3·49
50–59	2,333·0	35,885	15·38	606·0	4,729	7·80	1,028·5	10,202	9·92
60–69	954·5	45,536	47·71	181·5	7,427	40·92	386·5	9,652	24·97

TABLE IX.—*Males, 1923–27.—The number of person-years of exposure to risk, the duration of* SICKNESS *suffered and the number of claims made from* (1) *all causes of sickness less particular respiratory causes and* (2) *particular respiratory causes,* amongst the occupational groups in spinning mills.*

Age Group (age last birthday at beginning of year of exposure).	Strippers and Grinders and other Cardroom Workers.			Ring Room and Warehouse Workers.			Blowing-room and other Preparatory Workers and Workers in both Card and Blowing-room.		
	Person–years of exposure to risk.	Total duration of sickness in days. Total number of claims made.		Person-years of exposure to risk.	Total duration of sickness in days. Total number of claims made		Person-years of exposure to risk.	Total duration of sickness in days. Total number of claims made.	
		All causes less respiratory.	Respiratory causes.		All causes less respiratory.	Respiratory causes.		All causes less respiratory.	Respiratory causes.
16–19	695·5	2,715 125	354 8	1,337·0	5,875 246	659 21	323·0	1,358 54	162 3
20–29	1,944·0	7,539 313	1,203 45	1,897·5	7,120 285	1,275 38	852·0	2,443 127	332 10
30–39	3,663·5	11,831 493	3,453 121	1,570·5	4,858 190	446 15	859·5	3,315 114	1,110 31
40–49	3,865·0	15,750 484	6,825 252	1,363·0	5,428 175	695 25	1,223·0	5,522 200	2,177 72
50–59	2,351·0	14,118 406	10,821 298	610·0	2,712 86	833 18	1,039·5	6,861 203	4,035 114
60–69	961·5	10,836 220	8,880 196	183·5	2,210 40	814 15	389·0	4,631 102	1,719 51
Total number of *persons* exposed . .	3,165			1,661			1,115		

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* These respiratory causes comprise here and throughout bronchitis, bronchial catarrh, asthma, emphysema, congestion of the lungs and pneumonia.

TABLE X.—*Males, 1923–27.—The number of person-years of exposure to risk, the duration of* DISABLEMENT *suffered and the number of claims made from* (1) *all causes of disablement less respiratory causes and* (2) *particular respiratory causes, amongst the occupational groups in spinning mills.*

Age Group (age last birthday at beginning of year of exposure).	Strippers and Grinders and other Cardroom Workers.			Ring Room and Warehouse Workers.			Blowing-room and other Preparatory Workers and Workers in both Card and Blowing-room.		
	Person-years of exposure to risk.	Total duration of disablement in days. Total number of claims made.		Person-years of exposure to risk.	Total duration of disablement in days. Total number of claims made.		Person-years of exposure to risk.	Total duration of disablement in days. Total number of claims made.	
		All causes less respir-atory.	Respir-atory causes.		All causes less respir atory.	Respir-atory causes.		All causes less respir-atory.	Respir-atory causes.
16–19	440·0	8 1	— —	813·0	1,244 6	— —	213·5	33 1	— —
20–29	1,917·5	2,979 20	225 4	1,883·5	5,789 26	363 7	848·5	82 2	1,906 6
30–39	3,634·0	7,087 37	1,286 11	1,562·5	1,056 5	— —	844·0	24 2	40 1
40–49	3,836·5	16,546 65	6,948 58	1,351·5	3,037 17	612 4	1,214·5	3,095 18	1,140 8
50–59	2,333·0	18,715 87	17,170 86	606·0	3,911 16	818 4	1,028·5	7,503 32	2,699 18
60–69	954·5	28,741 117	16,795 83	181·5	6,651 29	776 4	386·5	6,748 29	2,904 12

TABLE XI.—*Males, 1923–27.—Sickness Rates.—The number of days of sickness per person-year of exposure and the number of claims per* 100 *person-years of exposure from* (1) *all causes of sickness less particular respiratory causes and* (2) *particular respiratory causes, amongst the occupational groups in spinning mills.*

Age Group (age last birthday at beginning of year of exposure).	Strippers and Grinders and other Cardroom Workers.		Ring Room and Warehouse Workers.		Blowing-room and other Preparatory Workers and Workers in both Card and Blowing-room.	
	Number of days of sickness per person-year of exposure. Number of claims per 100 person-years of exposure.		Number of days of sickness per person-year of exposure. Number of claims per 100 person-years of exposure.		Number of days of sickness per person-year of exposure. Number of claims per 100 person-years of exposure.	
(1)	All causes less respiratory. (2)	Respiratory causes. (3)	All causes less respiratory. (4)	Respiratory causes. (5)	All causes less respiratory. (6)	Respiratory causes. (7)
16–19	3·90	·51	4·39	·49	4·21	·50
	17·97	1·15	18·40	1·57	16·72	·93
20–29	3·88	·62	3·75	·67	2·87	·39
	16·11	2·31	15·02	2·00	14·91	1·17
30–39	3·23	·94	3·09	·28	3·86	1·29
	13·46	3·30	12·10	·96	13·26	3·61
40–49	4·07	1·77	3·98	·51	4·52	1·78
	12·52	6·52	12·84	1·83	16·35	5·89
50–59	6·01	4·60	4·45	1·37	6·60	3·88
	17·26	12·68	14·10	2·95	19·53	10·97
60–69	11·27	9·24	12·04	4·44	11·90	4·42
	22·89	20·38	21·80	8·17	26·22	13·11

TABLE XII.—1923–27. *Males.—The sickness rates of strippers and grinders and other cardroom workers expressed as a percentage of the similar rates of other groups of cotton operatives* (1) *for all causes of sickness less particular respiratory causes,* (2) *for particular respiratory causes.*

Age Group (age last birthday at beginning of year of exposure).	Strippers' and Grinders' and Cardroom Workers' rates as percentage of Ring Room and Warehouse Workers' rates.				Strippers' and Grinders' and Cardroom Workers' rates as percentage of Blowing-room and other Preparatory Workers' rates *			
	All causes less respiratory.		Respiratory causes.		All causes less respiratory.		Respiratory causes	
	Days of sickness.	Number of claims.	Days of sickness.	Number of claims.	Days of sickness	Number of claims.	Days of sickness.	Number of claims.
16–19	89	98	104	73	93	107	102	124
20–29	103	107	93	116	135	108	159	197
30–39	105	111	336	344	84	102	73	91
40–49	102	98	347	356	90	77	99	111
50–59	135	122	336	430	91	88	119	116
60–69	94	105	208	249	95	87	209	155

* Including workers in both card and blowing-room.

TABLE XIII.—1923–27. *Males.—Disablement Rates.—The number of days of disablement per person-year of exposure and the number of claims per* 100 *person-years of exposure from* (1) *all causes of disablement less particular respiratory causes and* (2) *particular respiratory causes, amongst the occupational groups in spinning mills.*

Age Group (age last birthday at beginning of year of exposure).	Strippers and Grinders and other Cardroom Workers		Ring Room and Warehouse Workers.		Blowing-room and other Preparatory Workers and Workers in both Card and Blowing-room.	
	Number of days of disablement per person-year of exposure. Number of claims per 100 person-years of exposure.		Number of days of disablement per person-year of exposure. Number of claims per 100 person-years of exposure.		Number of days of disablement per person-year of exposure. Number of claims per 100 person-years of exposure.	
(1)	All causes less respiratory. (2)	Respiratory causes. (3)	All causes less respiratory. (4)	Respiratory causes (5)	All causes less respiratory. (6)	Respiratory causes. (7)
16–19	·02	—	1·53	—	·15	—
	·23	—	·74	—	·47	—
20–29	1·55	·12	3·07	·19	·09	2·25
	1·04	·21	1·38	·37	·23	·71
30–39	1·95	·35	·68	—	·03	·05
	1·02	·30	·32	—	·24	·12
40–49	4·31	1·81	2·25	·45	2·55	·94
	1·70	1·51	1·26	·30	1·48	·66
50–59	8·02	7·36	6·45	1·35	7·30	2·62
	3·73	3·69	2·64	·66	3·11	1·75
60–69	30·11	17·60	36·64	4·28	17·46	7·51
	12·25	8·70	15·98	2·20	7·51	3·10

TABLE XIV.—1923–27. *Males.—The average duration of each sickness claim,* (first 26 weeks of incapacity) from* (1) *all causes of sickness less particular respiratory diseases and* (2) *particular respiratory diseases, amongst the occupational groups in spinning mills. In days.*

Age Group (age last birthday at beginning of year of exposure).	16–19.		20–29		30–39		40–49		50–59		60–69.	
	All causes less respir-atory	Respir-atory causes	All causes less respir-atory	Respir-atory causes.	All causes less respir-atory	Respir-atory causes.	All causes less respir-atory.	Respir-atory causes	All causes less respir-atory.	Respir-atory causes	All causes less respir-atory.	Respir-atory causes.
Strippers and grinders and other cardroom workers	22	44	24	27	24	29	33	27	35	36	49	45
Ring-room and warehouse workers ..	24	31	25	34	26	30	31	28	32	46	55	54
Blowing-room and other preparatory workers and workers in both card and blowing-room	25	54	19	33	29	36	28	30	34	35	45	34
Strippers and grinders, etc., as percentage of ring-room and warehouse workers	*92*	*142*	*96*	*79*	*92*	*97*	*106*	*96*	*109*	*78*	*89*	*83*
Strippers and grinders, etc,, as percentage of blowing-room workers, etc	*88*	*81*	*126*	*82*	*83*	*81*	*118*	*90*	*103*	*103*	*109*	*132*

* Each period of sickness was counted as a claim irrespective of whether it was " linked-up " with another period or not. Since, to avoid overlapping age-groups, the sickness was analysed for each calendar year separately and then totalled for the 5 years, a claim running into two calendar years appeared as two in the total The duration is therefore the duration within the calendar year

Number of claimants from respiratory diseases in the cotton operative groups.—A further point that arises is whether this larger number of claims made by the strippers and grinders is derived from an actually larger number of *persons* claiming or rather from an excess of persons making a large number of claims each. The answer is that both factors seem to be responsible, and the figures are given in Tables XV and XVI. The former table shows for the three occupational groups the number of persons who were ill (either one or more times during the 5 years) with respiratory complaints, this number being given in absolute and percentage form (as per cent. of total number of persons exposed). At ages 16–24 the percentage ill from these causes is lowest amongst the cardroom workers, showing that initially they are not peculiarly liable to these diseases. At ages 20–34 the cardroom group has an appreciably higher percentage of persons ill from these causes than those found in the other groups. In all the later age groups the cardroom workers have approximately twice as high a proportion of persons ill from respiratory causes as the ring-room and warehouse workers. The blowing-room workers show higher percentages at ages 30–54 and lower percentages from 50–69. The difference between them and the cardroom workers is, as before, not distinct.

The incidence of multiple claims.—Table XVI shows that, amongst the cardroom group, as compared with the ring-room and warehouse group, as well as a relatively larger number of persons making claims for respiratory causes, there were a large number of persons in the older age groups who were compelled to have recourse to benefit on repeated occasions. The numbers involved are small but both the older age groups give the same result. At ages 30–54 out of those claiming benefit from respiratory causes, amongst the strippers and grinders 51·3 per cent. made only one claim, 33·5 had to claim twice and 15·2 per cent. had to claim four or more times. Amongst ring-room and warehouse workers, on the other hand, 70·4 per cent. of the claimants claimed once only, 22·2 per cent. claimed twice and only 7·4 per cent.—or half as many as in the cardroom group—had to make four or more claims. At ages 50–69 the differences are still more distinct. When the cardroom group is compared with the blowing-room group, the differences as usual are found to be slighter.

In other words this population of strippers and grinders, etc., in comparison with ring-room and warehouse workers contains not only more persons in the older age groups who were ill during 1923–27 from respiratory illnesses (Table XV) but also more persons who had repeated attacks of respiratory illnesses (Table XVI).

TABLE XV.—1923–27. *Males.—The number of persons in each occupational group who claimed benefit (once or more times) during the five years because of sickness of a respiratory nature, shown absolutely and as a percentage of the number of persons exposed to risk.*

Age Group* (age last birthday at beginning of year of exposure).	Strippers and Grinders and other Cardroom Workers.			Ring-room and Warehouse Workers			Blowing-room and other Preparatory Workers and Workers in both Card and Blowing-room.		
	Number of persons exposed to risk.	Number of persons making claims from respiratory causes.	Column (3) as percentage of column (2).	Number of persons exposed to risk.	Number of persons making claims from respiratory causes.	Column (6) as percentage of column (5).	Number of persons exposed to risk.	Number of persons making claims from respiratory causes	Column (9) as percentage of column (8).
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
16–24	340	12	3·5	572	27	4·7	147	6	4·1
20–34	466	40	8·6	334	19	5·7	192	8	4·2
30–44	885	78	8·8	355	11	3·1	218	23	10·6
40–54	813	119	14·6	259	16	6·2	269	42	15·6
50–64	474	121	25·5	104	14	13·5	220	41	18·6
60–69	187	68	36·4	37	8	21·6	69	17	24·6

* Since, for this purpose, a claim was counted as only one when it ran into two or more calendar years, overlapping age groups are produced. The number of persons exposed to risk, *e g* , 340 cardroom workers aged 16 to 24, is the number aged between 16 and 19 (age last birthday) at 1.1.23 or at any later entry date. Obviously by 1927 some of these persons will have moved into the next age group, 20–24, so that during the years 1923–27 they are of ages 16 to 24. Similarly the ages in the next age group cover the years 20 to 34.

TABLE XVI.—1923–27. *Males.—The number of persons making one or more claims from respiratory causes, grouped according to the number of claims made.*

Age Group (age last birthday at beginning of year of exposure).		Number of Persons making a claim or claims from respiratory diseases.	Percentage of total number claiming from respiratory causes who claimed from such causes during the 5 years :—			
			Once.	2–3 times.	4–5 times.	6 and more times.
16–34	Strippers and grinders and other card-room workers	52	76·9	19·2	1·9	1·9
	Ring-room and Warehouse workers ..	46	84·8	10·9	2·2	2·2
	Blowing-room workers, etc.	14	71·4	28·6	—	—
30–54	Stripping and grinders and other card-room workers	197	51·3	33·5	9·1	6·1
	Ring-room and Warehouse workers ..	27	70·4	22·2	7·4	—
	Blowing-room workers, etc	65	66·2	23·1	9·2	1·5
50–69	Stripping and grinders and other card-room workers	189	51·3	32·3	11·1	5·3
	Ring-room and Warehouse workers ..	22	81·8	13·6	4·5	—
	Blowing-room workers, etc.	58	50 0	31·0	15·5	3·5

Consideration of the elimination of the incapacitated from the cardroom.—It must be remembered too that these differences shown between cardroom workers and the other groups of operatives may not show the true position of the cardroom group. If there is any appreciable proportion of persons who work in the cardroom but who are forced to leave it, either because they cannot endure its environment or because their health is affected, then the disparity in rates between this group and the other groups is reduced and is smaller than the true disparity. It is for this reason that the second subsidiary group has been examined—those persons who once worked in the cardroom but had ceased to do so in 1923–27.

At first sight the distribution of the exposed to risk in Table VII would suggest that there was an influx of workers to the cardroom rather than an efflux, since the numbers increase to beyond age 40. This is not necessarily contradictory evidence. The cotton spinning industry has made practically no expansion since 1909. This is shown in the following figures* :—

Estimated Number of Spindles in Great Britain.
1913 = 100.

1900	73
1905	81
1909	97
1910	98
1911	98
1912	99
1913	100
1920	101
1921	101
1922	101
1923	100
1924	101
1925	102
1926	102

Between 1909 and 1926 there has only been a five per cent. increase in the number of spindles. This means that the number of entries to the trade has, since 1909, been practically dependent upon the number of exits—from death or other causes. There were large numbers of entries at the end of the nineteenth and beginning of the twentieth centuries when the industry was quite rapidly expanding but this entry rate must have come to an end by 1909. The result is that the larger numbers who entered before 1909 are found in the older age groups at 1923 and there are smaller numbers in the younger age groups owing to the slackening of this rate of increase.† (The effect of the war casualties would also be to produce a higher age distribution.) Naturally there may be some influx too—of workers from the blowing or cotton rooms or of piecers who see no prospect of becoming spinners.

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* Daniels and Jewkes. The Post-War Depression in the Lancashire Cotton Industry. Journ. Roy. Stat. Soc., XCI. Part II, p. 165, 1928.

† For instance in 1923 the strippers and grinders here dealt with gave a total of 2,774·5 years of exposure, 21 per cent. being at ages 16–29, 57 per cent. at ages 30–49 and 22 per cent. at ages 50–69. In 1927 the years of exposure were 2,622·0, those at ages 30–49 having fallen to 54 per cent., and those at ages 50–69

The ring-room and warehouse workers do not show this older age distribution, probably because of the large efflux of young ring-room workers who have no prospect of reaching more highly paid work.

Thus there may be an efflux of workers from the cardroom in spite of the distribution of persons increasing with age.

Eighteen persons definitely stated on their questionnaires that they left the cardroom because their health was affected by the dust, which agrees with Collis's suggestion that there is some elimination of persons whose health is damaged. The absolute figures and rates for the whole group are given in Table XVII and compared with those already given for the strippers and grinders and other cardroom workers (in Table XI).* Comparison of the rates from all causes less respiratory shows that the " ex-cardroom " workers have considerably higher rates than the " present " cardroom workers, especially at the younger ages. It is possible that this is due to a process of selection. Workers who leave their original occupation may be of weaker physique and leave their employment through ill-health (apart from that acquired by environment), so that the population remaining in the particular occupation is to some extent the more physically fit. Unless the control groups are equally stringently selected (and on that point no information is available) the relative position of the cardroom group is understated. Comparing the rates from respiratory diseases (columns 6 and 8) it will be seen that the ex-cardroom workers are, at least, as badly off as the present cardroom workers. (The rates are based on small numbers and fluctuate erratically, in some age groups being below and in some age groups above the strippers' and grinders' rates). In other words the rates *suggest* (though in the absence of similar information for the control group they cannot prove) an elimination from the cardroom of persons who suffer from respiratory complaints, and continue so to suffer even after they have ceased to work in the environment. No doubt persons with asthmatic tendencies, quite apart from any environmental cause, would tend to forsake an occupation in which they were exposed to dust and thus contribute to the respiratory rates of the "ex-cardroom" group. To some extent, therefore, the position of the cardroom workers in comparison with the workers in the ring-room and warehouse is probably an understatement, and the excess of respiratory complaints, it is suggested, is modified by the fact that there is some elimination from the cardroom of workers who lose their health in it. Some of these workers continue to suffer from bronchitic complaints although they have left the cardroom environment, indicating that their health is impaired. This leads to one important point of this inquiry.

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* The population of " ex-cardroom " workers was too small to allow

TABLE XVII.—*Males* 1923–27.—*Sickness amongst workers not in the cardroom during* 1923–27 *but who had previously worked in that room (ex-cardroom workers) compared with the sickness of strippers and grinders and other cardroom workers in* 1923–27.

Age Group (age last birthday at beginning of year of exposure). (1)	Ex-Cardroom Workers					Strippers and Grinders and other Cardroom Workers.	
	Person-years of exposure to risk. (2)	Total duration of Sickness in days. Total Number of Claims made.		Number of Days of Sickness per person-year. Number of Claims per 100 person-years.		Number of Days of Sickness per person-year Number of Claims per 100 person-years.	
		All Causes less Respiratory. (3)	Respiratory Causes. (4)	All causes less Respiratory (5)	Respiratory Causes. (6)	All Causes less Respiratory (7)	Respiratory Causes. (8)
16–19	149·5	916	39	6·13	·26	3·90	·51
		34	4	22·74	2·68	17·97	1·15
20–29	617·5	3,451	242	5·59	·39	3·88	·62
		149	8	24·13	1·30	16·11	2·31
30–39	560·0	2,945	509	5·26	·91	3·23	·94
		113	23	20·18	4·11	13·46	3·30
40–49	632·5	3,852	2,469	6·09	3·90	4·07	1·77
		110	65	17·39	10·28	12·52	6·52
50–59	590·5	3,842	3,811	6·51	6·45	6·01	4·60
		107	95	18·12	16·09	17·26	12·68
60–69	240·0	2,711	1,752	11·30	7·30	11·27	9·24
		46	32	19·17	13·33	22·89	20·38
Total Number of Persons exposed.	646						

The origin of the high respiratory rates amongst strippers and grinders.—Are the high respiratory rates found amongst strippers and grinders a product of the past, the sickness being confined to persons whose health was impaired by the conditions previous to the introduction of exhaust ventilation and vacuum for stripping, or are present conditions still producing this excess of respiratory incapacity? Professor Collis in his report of 1908 already quoted (p. 12) expressed the opinion that these improvements would solve the problem and that only the irreparably damaged workers would still suffer. The Trade Union representatives dispute this. The rates of the "ex-cardroom" workers suggest that the excess *does* continue even though the environment is changed, so that it seems probable that the very high rates at the older ages are, at least in part, due to the bad environment to which the older workers were exposed for many years. No excess of respiratory illness is found amongst the younger workers, under age 30, and any operatives over this age in 1923–27 must have been, at least for some time, exposed to the old conditions. This absence of abnormal rates under age 30 and the sudden jump in incidence after that age certainly suggests the presence of previously damaged lives in the older age groups. On the other hand, even if this is so it cannot prove that modern conditions are not injurious to health. It may well be that some years' exposure is needed before health is damaged sufficiently to be apparent in sickness incidence, and workers who have had prolonged exposure can appear only in the older age groups. Evidence that it does not need the extreme of dust and fibre blown out during the old methods of stripping and grinding to produce such an excess of respiratory illness might be adduced from the fact that an excess of these forms of illness is found amongst workers engaged in the earlier cleansing processes —mixing, blowing and scutching. This evidence is very much weakened, however, by the fact that there is (as previously pointed out) a considerable interchange of labour between the cardroom and these other rooms. The excess amongst the latter may only be due to their recruitment from the former of operatives whose health is damaged. In addition no data are available showing the actual prevalence of dust and fibre in these various rooms.

It might be thought that examination of the annual movement of the sickness rates during 1923 to 1927 would show whether the incidence of respiratory diseases is becoming less acute, through the gradual elimination of such operatives with damaged health, or whether the incidence is still maintained by the addition of persons incapacitated by the present environmental conditions. Actually such evidence may not be valid. The sickness incidence of the general insured population of the whole country has been rising fairly steadily over the last few years. This phenomenon is probably explicable in terms of quite a number of causes, *e.g.*, epidemics, wage levels, unemployment, and in discussing the movement from year to year it is impossible to isolate the effect of any one particular factor. In the population here dealt with it probably would not be possible to distinguish between these general factors affecting its sickness experience and the one particular factor—the environment—with which the inquiry is specially concerned. In addition the number of persons involved in the inquiry is too small to allow any such analysis to give reliable results. The final conclusion must be that, at present, sickness statistics do not afford any evidence that modern conditions *are* producing an abnormal amount of respiratory sickness amongst the male workers in the cardroom, but that this lack of evidence is not conclusive since valid evidence *of this type* cannot be obtained until another ten or fifteen years have elapsed After that time there will exist a population of cardroom workers who have been exposed for a considerable number of years to the improved conditions only, and it will be possible to see then whether they, like the workers who were exposed to the pre-vacuum stripping conditions, suffer abnormally from respiratory illness.

Comparison of sickness between mills spinning coarse and fine counts.—One of the questions asked on the occupational questionnaire circulated to the members of the Insurance Section of the Cardroom Association related to the mill or mills in which the operatives worked during 1923–27. It was hoped, on the basis of the answers, that it would be possible to divide up the workers according to whether they worked in a mill spinning "coarse, medium or fine counts." The importance of the difference lies in two points :

(1) where coarse counts are to be spun rather more stripping (*i.e.*, cleaning of the carding wires) must be carried out. Also during the carding process itself it is stated that more fibres are thrown off into the air ;

(2) the finer counts are spun mainly from Egyptian cotton and the coarser from American cotton. It has been suggested that the dust eliminated from the Egyptian cotton may be finer and sandier than that contained in the American cotton, and may be more or less injurious to health if inhaled.

Unfortunately it was found impracticable to divide the workers up on this basis of counts spun, the first reason being that there was, in the five years, a considerable interchange of labour between mills. Calculation of the length of exposure to risk in each would have been an elaborate procedure, and, also, in the case of sickness it would have been quite arbitrary whether it was debited to the mill in which the man was at work at its onset or to a mill which he had recently left—which might belong to a different category when judged by the counts spun. A second, and still more important, source of fallacy was found in the absence of reply in some cases, especially for workers who had died. To ignore these would be possibly to exclude the very persons with whom the study was largely concerned. On the other hand it was possible to attempt one very broad comparison. In the Oldham district is situated a large part of the "American" section of the industry. In Bolton the mills are mainly devoted to spinning with Egyptian cotton the finer counts of yarn. Neither district is *absolutely* confined to one type; in Oldham there are some fine spinning mills while in Bolton there are to be found coarse spinning mills, but, as a whole, Oldham may fairly be taken for the "coarse" category and Bolton as the "fine." Between the two towns the interchange of labour is relatively slight (the males who worked in both towns during 1923–27 numbered only one or two), and the town of residence was known for all members, alive or dead. As a rough comparison, therefore, of the coarse and fine spinning mills the claim rates for the cardroom group of workers were worked out for Oldham and its immediately surrounding district (*e.g.*, Middleton, Hollinwood) and for Bolton. Unfortunately the numbers involved (in the Oldham group there were 914 workers and in Bolton 265) were so small that the rates were too unreliable to allow any deductions to be made, and they have therefore been rejected. In other words, this investigation did not allow the sickness experience to be related to the type of cotton and number of counts spun.

Unemployment and rates of pay.—A sickness rate may be the result of many factors, *e g.*, working environment, living environment, poverty and unemployment. With regard to the last mentioned factors it is possible that a man who is unemployed or on low wages is more inclined to "sign on" and draw benefit when ill than a man in full employment earning high wages. The former has little to lose, the latter loses according to the difference between his wages and the level of the sickness benefit he can draw. It does not seem likely that such factors are operative in producing the differences found between strippers and grinders and other cardroom workers on the one hand and the rest of the workers in the spinning mills on the other. Their influence, it would seem, would be operative on most forms of sickness and not so very especially on the respiratory forms. It may be of service, however, to consider these points.

The living environment does not differ materially between the groups. They are all situated in the same Lancashire towns and under much the same housing and sanitary conditions. In wage the cardroom workers have some advantage. During the years 1923–27 the average earnings of a stripper and grinder for a *full working week* were £3 4*s*. The carder would receive considerably more than this and the undercarder a little more. In the ring-room the overlooker would be about on a par with the carder or undercarder, but the jobbers would earn less than the strippers and grinders. The average wage in the ring-room would be about £2 2*s*. per week against about £3 in the cardroom. The cardroom workers would be also better off than the warehouse group which is composed chiefly of cop packers on a wage of about £2 14s. for a full week.

Actually, of course, in these years a full week was not being worked. There was a considerable amount of unemployment and short-time (the latter at least an average of 25 per cent. of full time). On the other hand this factor affects all groups nearly equally, since the work of one group is dependent upon that of the other. If the cardroom is unemployed the spinners and warehouse workers must shortly become unemployed too. What lack of balance there is affects the preparatory workers slightly more than the spinning section, but the difference is not sufficient for this factor to be an important one in discussing such disparate sickness rates. In addition it must be remembered that the factor of the working environment, which is the crucial point in the inquiry, is weakened by the amount of short-time worked and unemployment experienced. The cardroom workers are not exposed for so long a day to the environment of which they make complaint. If their conditions of work are responsible for their high level of respiratory illness, it is possible that, in this period of years, their sickness rates are below normal through absence of normal exposure.

A psychological factor might contribute to the strippers' and grinders' excess of bronchitis. If it is generally believed amongst these workers that they are likely to suffer from such illness they may be more prone to " sign on " at such attacks or to translate other symptoms into respiratory symptoms, while there might be a tendency for local medical practitioners to certify respiratory sickness more easily amongst operatives whom they know are exposed to a dusty environment. Though such psychological tendencies might contribute to the rates found it cannot be held possible that they could produce such very large discrepancies as have been found.

There is, therefore, on the whole, no evidence of any important influences to explain the differing sickness rates of the groups except that of the environmental conditions of work.

FEMALES.

Occupations.

In the description given of the processes carried out and the environment in the cotton spinning mill (*vide* pp. 7–11) it was pointed out that women are largely employed in three distinct parts of the mill. These are (1) as machine " tenters " in that section of the cardroom (or infrequently in another room altogether) which contains the ribbon lap machines, draw-frames, and speed-frames; (2) as ring spinners in the ring spinning room; and (3) as winders and reelers in the winding, warping and reeling department. The machine tenters in the cardroom, it was pointed out, are exposed, to a minor extent, to the dust and fibre evolved in the carding and stripping and grinding processes. The can tenters who remove the full cans of slivers from the carding machines and replace them with empty ones are, probably, of the women, most exposed to the dust. The tenters on the frames the other side of the cardroom are involved only in so far as the dust is blown from one side of the room to the other. On the other hand they may be exposed to additional floating fibre produced in their own processes. As regards *dust* the problem for all the women in the cardroom must certainly be far less acute than it is for the male strippers and grinders.

The occupations of the female members of the Association of Card, Blowing and Ring Room Workers were ascertained by questionnaire as described on p. 23. Particulars were obtained for 28,634 out of the 30,101 members, or for 95 per cent. For the remaining 1,467 occupation at entry into the Society was used. Some of these may have transferred to other occupations before or during the period of years investigated, but the total proportion involved is so small that it could have no appreciable effect upon the sickness rates found. For members of the Operative Spinners' and Amalgamated Weavers' Societies occupation at entry into the Society was used in all cases, and, again some of these may have transferred before 1923 to other occupations. The numbers found in each occupation are set out in Table XVIII. Just over 20,000 members of the Association of Card, Blowing and Ring Room Workers were found in the cardroom, made up of a small proportion of can tenters near the carding engines and a very large proportion of machine tenters on the speed and draw frames and combing machines. Only 147 workers were returned as being employed in the blowing and cotton rooms. These have been added to the cardroom group, being too few in number to serve any other purpose. This Society provided also a comparative group of approximately 5,000 spinners. To the second control group of winders, reelers, etc., the Cardroom Association contributed 1,151 members, and the Operative Spinners 179 and Amalgamated Weavers 1,347. Thus there are three main occupational groups to examine, as follows :—

Cardroom workers .. .. (all members of Cardroom Association, A.S. 1265).	20,500
Spinners and allied workers .. .. (all members of Cardroom Association, A.S. 1265).	5,243
Winders, reelers and allied workers .. .. .. (members of Cardroom Association, A.S. 1265, Operative Spinners, A.S. 1144 and Amalgamated Weavers, A.S. 1111).	2,677

Table XVIII shows that there is a certain amount of transference of workers between the cardroom and the spinning and winding rooms. In the years covered by the inquiry 160 workers were found in the spinning room, and 353 workers in the winding room, who had previously worked in the cardroom. The proportion of spinners who had at one time been cardroom workers is not high so that this comparative group is probably little affected by such transference. With winders on the other hand the proportion is very considerable—out of 1,504 such workers belonging to the Cardroom Association 353 or roughly one quarter had once been in the cardroom. Over half of this control group is made up of members of the Amalgamated Weavers' and Operative Spinners' Societies whose occupation was taken as the occupation *at entry* into those Societies. It is thus quite probable that some of these workers had previously worked in the cardroom but no such information being available (except for members of the Cardroom Association) they have been included in the winders' group. For this reason, that it may contain a proportion of workers who once worked in the cardroom, the winders' group is a less satisfactory comparative group than is the spinners' group, which is unlikely to contain any appreciable number of transferred workers. It is also a less reliable control group because half of the exposed persons belong to other Approved Societies, and differences of administration may affect sickness rates appreciably. The spinners and cardroom workers all belong to the same society, *i.e.*, the Association of Card, Blowing and Ring Room Operatives. The members of the Cardroom Association who were thus found in spinning or winding rooms but who previously worked in cardrooms have not been included in the comparative groups. They were too few in number to be treated separately, but analysis has been made of those members who were found in 1923–27 outside the trade but who were originally in the cardroom. Those outside the trade who gave no reference to previous mill work have been excluded altogether from the investigation, as have also the few workers in other mill employment and the prolonged cases of workmen's compensation.

TABLE XVIII.—*The numbers found in each occupational group amongst female members of the Card, Blowing and Ring Room Insurance Approved Society.*

Can tenters, engine head tenters, speed frame and draw frame tenters (i.e., slubbers, rovers, combers, etc.) ..	20,353	
Cotton room, cotton mixing and cotton chamber workers	93	
Blowing room operatives	54	
		20,500
Ring spinners, ring-room workers and thread doublers..		5,243
Winders, beamers, reelers and warpers		1,151
Outside the trade in 1923–27, but previously in the cardroom		1,162
Spinning room workers in 1923–27 who previously worked in the cardroom	160	
Winding-room workers in 1923–27 who previously worked in the cardroom	353	
Outside the trade in 1923–27 and no reference to previous mill work	1,404	
Odd jobs in mill: warehouse workers, roller coverers, and other odd jobs	92	
On workmen's compensation benefits during all or most of 1923–27	36	
		2,045
Total ..		30,101

Sickness.

No occupational mortality statistics exist for women and there is no other evidence as to their health in these particular employments and environments. Reference to the sickness statistics collected in this inquiry may, therefore, be immediately made. The analysis has been carried out separately for single (including widowed) and married women, since it is well known that the incidence of sickness differs widely in the two groups. Single women who married during 1923 to 1927 were transferred to the married group at the appropriate date and their exposure continued in the married group.* In Table XIX are set out the figures relating to all causes of sickness for the three occupational groups of single women. In Table XX similar figures are given for the disablement experience of the single women.

The analysis followed precisely the same course as was adopted for the men, the only differences being the separation of the single from the married, and some change in the age groups made expedient by the numbers exposed to risk. There were sufficient women aged 20 to 29 to make it possible to divide this age group into two, 20–24 and 25–29 years, while there were too few over age 50 to make any further subdivision advisable. In addition there were too few *married* women of ages 16 to 19 to serve any purpose at all (especially as their sickness was predominantly that associated with pregnancies), so that no rates are given for married women under 20 years of age.

Women, Single and Widowed.

Sickness and Disablement rates of the occupational groups from all causes of Illness, and from respiratory causes.

Table XIX shows that, from all causes of sickness taken together, the cardroom workers suffer less than either the ring spinning group or the winding and reeling group. The figures suggest that their rates may be in excess in the final age groups but the numbers exposed at these ages in the control groups are too small to allow the differences to be stressed. For the same reason the disablement figures are not very satisfactory. Taken as a whole the cardroom workers seem to have higher rates than the ring spinners, but higher rates than the winders in only two of the six age groups so that it is difficult to accept the differences as significant.

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* To save time women who became widows during the period of investigation were *not* transferred from the married to the single group. The number was small and their transference or non-transference was immaterial

Women who at or after marriage were transferred to Class K were made exits at date of marriage and not kept in the exposed to risk for their period in Class K.

When the sickness experience is divided into sickness from respiratory causes (these causes being, as with the men, bronchitis, bronchial catarrh, asthma, emphysema, congestion of the lungs and pneumonia) and sickness from non-respiratory causes (Tables XXI to XXV), the results found are as follows :—the workers in the cardroom have, up to age 50, *less* sickness from *non-respiratory causes* than the ring spinners. At ages 50–69 they have some excess. From *respiratory causes* there is little difference between the two groups before age 24, but after that age the cardroom workers have a *distinct excess* of such forms of illness (*vide* Table XXIV and fig. (ii).). In other words although these single women between the ages of 25 and 49 in the cardroom suffer less than the ring spinners from non-respiratory causes of illness they certainly suffer more from respiratory forms.

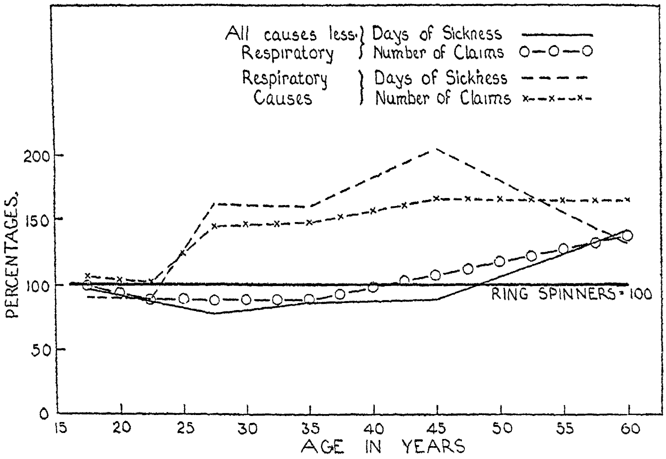

FIG. (ii).

1923–27. Sickness rates found for Cardroom Workers, FEMALES, single and widowed (days of sickness per person-year and number of claims per 100 person-years), expressed as percentages of the rates found for Ring Spinners and Allied Workers.

Comparing them with the winders and reelers it is seen that the sickness rates from *all causes less respiratory causes* of winders and reelers do not differ very widely from the rates of the cardroom workers. Up to age 40 the cardroom workers suffer to a slightly less extent. The percentages in Table XXIV show that the difference, except at ages 25–29, is not large. At ages 40–49 the cardroom workers show some excess (though shorter claims, *vide* Table XXVI) ; at ages above 50 there is again little difference. From *respiratory causes* the cardroom workers show some excess of claims in every age group—including the earlier ages, under 24—and an excess of days of sickness in four of the six age groups.

The exposed to risk in the winders' occupational group is small and discussion of the level of the rates in particular age groups is not justifiable.

The general conclusion is that the cardroom workers have a little less sickness than both spinners and winders and reelers *except* in the case of respiratory diseases. Of respiratory diseases the cardroom workers have some excess, but by no means the excess found for the males. The male strippers' and grinders' rates from respiratory diseases after age 30 were found to be two and three times as high as the corresponding rates for ring-room and warehouse operatives. Comparison of figures (i) and (ii) shows that the excess amongst these females (single and widowed) is considerably less than this.

The disablement rates are, as already pointed out, based upon too small numbers to allow detailed consideration. The cardroom workers have an excess of respiratory disablement when compared with the winders but not when compared with the spinners. Little reliance can be placed upon this result.

The duration of sickness claims.—Table XXVI shows that the excess of short-period respiratory illness amongst cardroom workers is due more to a *larger number of claims* being made than to a disproportionate *length of claim.* The cardroom workers have, from ages 25 to 50, it is true, an average length of sickness somewhat higher than that of the spinners, but this excess (109, 109 and 122 per cent. of the spinners' duration in the three age groups) is less than their excess in number of claims (146, 149 and 166 per cent. of the spinners' claims). Compared with the winders and reelers their average duration of claim is higher in four out of the six age groups, but, again, except at ages 16–19, the excess in duration is not so large as the excess in claims made. It therefore appears that the excess of respiratory illness amongst the single women is due partially to *more* claims being made, and partially to *longer* claims being made, the former being the more important factor.

With the men the larger number of claims made in the cardroom was further analysed to show that it was composed both of more persons claiming and of more persons making repeated claims. This analysis has not been carried out for the women partly because their excess of illness from respiratory causes is so much less than the excess amongst the men, and partly because so many women transfer from the single to the married group during the inquiry that the definition of a repeated claimant, if the single and married groups are kept distinct, must be very artificial.

TABLE XIX.—*Females, single and widowed,* 1923–27.—*The* SICKNESS *experience from all causes.*

	Workers in the Cardroom.			Ring Spinners and Allied Workers.				Winders, Reelers and Allied Workers.			
Age Group (age last birthday at beginning of year of exposure).	Person-years of exposure to risk.	Total duration of sickness in days.	Number of days of sickness per person-year of exposure.	Person-years of exposure to risk.	Total duration of sickness in days.	Number of days of sickness per person-year of exposure	Card-room Workers as percentage of these Ring Spinners and Allied Workers.	Person-years of exposure to risk	Total duration of sickness in days.	Number of days of sickness per person-year of exposure	Card-room Workers as percentage of these Winders, Reelers and Allied Workers.
16–19	14,213·5	91,898	6·47	4,468·5	30,365	6·80	95	2,157·5	14,054	6·51	99
20–24	11,336·0	85,632	7·55	3,689·0	32,211	8·73	86	2,070·0	16,974	8·20	92
25–29	6,322·0	42,197	6·67	1,447·5	11,898	8·22	81	935·5	8,447	9·03	74
30–39	8,109·5	65,325	8·06	1,954·0	17,333	8 87	91	1,316·5	10,934	8·31	97
40–49	4,376·5	44,794	10·24	617·0	6,411	10·39	99	577·5	4,777	8·27	124
50–69	3,434·5	59,245	17·25	246·0	3,066	12·46	138	266·0	4,620	17·37	99
Total number of *persons* exposed	13,251			3,423				1,974			

TABLE XX.—*Females, single and widowed,* 1923–27.—*The* DISABLEMENT *experience from all causes.*

Age Group (age last birthday at beginning of year of exposure).	Workers in the Cardroom.			Ring Spinners and Allied Workers.			Winders, Reelers and Allied Workers.		
	Person-years of exposure to risk.	Total duration of disablement in days.	Number of days of disablement per person-year of exposure.	Person-years of exposure to risk.	Total duration of disablement in days.	Number of days of disablement per person-year of exposure.	Person-years of exposure to risk.	Total duration of disablement in days.	Number of days of disablement per person-year of exposure.
16–19	8,422·5	7,668	·91	2,835·0	1,850	·65	1,399·5	1,512	1·08
20–24	11,265·5	36,288	3·22	3,660 0	10,158	2 78	2,049·0	7,186	3·50
25–29	6,255·0	28,566	4·57	1,428·0	7,340	5·14	918·5	2,198	2·39
30–39	7,977·5	50,385	6·32	1,881·5	8,809	4·68	1,290·5	5,225	4·05
40–49	4,300·5	46,462	10·80	604·5	3,819	6·32	554·5	6,593	11·89
50–69	3,367·0	113,479	33·70	239·5	3,905	16·30	259·0	8,093	31·25

TABLE XXI.—*Females, single and widowed,* 1923–27.—*The number of person-years of exposure to risk, the duration of* SICKNESS *suffered and the number of claims made from* (1) *all causes of sickness less particular respiratory causes and* (2) *particular respiratory causes, amongst the three main occupational groups in spinning mills.*

Age Group.	Workers in the Cardroom.			Ring Spinners and Allied Workers			Winders, Reelers and Allied Workers.		
(Age last birthday at beginning of year of exposure).	Person-years of exposure to risk.	Total duration of Sickness in days. Total number of Claims made.		Person-years of exposure to risk.	Total duration of Sickness in days. Total number of Claims made.		Person-years of exposure to risk.	Total duration of Sickness in days. Total number of Claims made.	
		All Causes less respiratory.	Respiratory Causes.		All Causes less respiratory.	Respiratory Causes		All Causes less respiratory	Respiratory Causes.
16–19	14,213·5	84,560 3,385	7,338 221	4,468·5	27,805 1,076	2,560 65	2,157·5	13,336 510	718 31
20–24	11,336·0	78,662 2,811	6,970 218	3,689·0	29,664 1,050	2,547 69	2,070·0	16,226 548	748 28
25–29	6,322·0	37,921 1,234	4,276 121	1,447·5	11,286 323	612 19	935·5	7,735 214	712 15
30–39	8,109·5	57,145 1,672	8,180 228	1,954·0	16,105 458	1,228 37	1,316·5	9,997 278	937 30
40–49	4,376·5	36,937 968	7,875 201	617·0	5,870 126	541 17	577·5	4,012 89	765 22
50–69	3,434·5	43,228 922	16,017 368	246·0	2,204 48	862 16	266·0	3,333 75	1,287 27
Total number of *persons* exposed	13,251			3,423			1,974		

TABLE XXII.—*Females, single and widowed,* 1923–27.—*The number of person-years of exposure to risk, the duration of* DISABLEMENT *suffered and the number of claims made from* (1) *all causes of disablement less particular respiratory causes and* (2) *particular respiratory causes, amongst the three main occupational groups in spinning mills.*

Age Group.	Workers in the Cardroom.			Ring Spinners and Allied Workers.			Winders, Reelers and Allied Workers.		
(Age last birthday at beginning of year of exposure).	Person-years of exposure to risk.	Total duration of disablement in days. Total number of Claims made.		Person-years of exposure to risk.	Total duration of disablement in days. Total number of Claims made.		Person-years of exposure to risk.	Total duration of disablement in days. Total number of Claims made.	
		All Causes less respiratory.	Respiratory Causes.		All Causes less respiratory.	Respiratory Causes.		All Causes less respiratory.	Respiratory Causes.
16–19	8,422·5	6,463 67	1,205 18	2,835·0	1,308 20	542 2	1,399·5	1,400 16	112 4
20–24	11,265·5	33,174 216	3,114 25	3,660·0	8,259 72	1,899 14	2,049·0	7,095 53	91 2
25–29	6,255·0	25,845 119	2,721 20	1,428·0	6,840 38	500 4	918·5	2,146 24	52 1
30–39	7,977·5	46,903 215	3,482 28	1,881·5	7,704 57	1,105 11	1,290·5	5,066 38	159 2
40–49	4,300·5	36,989 170	9,473 50	604·5	3,767 22	52 1	554·5	3,196 25	3,397 19
50–69	3,367·0	85,414 349	28,065 144	239·5	1,822 12	2,083 9	259·0	7,408 29	685 4

TABLE XXIII.—*Females, single and widowed,* 1923–27.—SICKNESS RATES. *The number of days of sickness per person-year of exposure and the number of claims per* 100 *person-years of exposure from* (1) *all causes of sickness less particular respiratory causes and* (2) *particular respiratory causes, amongst the three main occupational groups in spinning mills.*

Age Group.	Workers in the Cardroom.		Ring Spinners and Allied Workers.		Winders, Reelers, and Allied Workers.	
(Age last birthday at beginning of year of exposure.)	Number of days of sickness per person-year of exposure. Number of claims per 100 person-years of exposure.		Number of days of sickness per person-year of exposure. Number of claims per 100 person-years of exposure		Number of days of sickness per person-year of exposure. Number of claims per 100 person-years of exposure.	
(1)	All Causes less Respiratory (2)	Respiratory Causes. (3)	All Causes less Respiratory. (4)	Respiratory Causes. (5)	All Causes less Respiratory. (6)	Respiratory Causes. (7)
16–19 . .	5·95	·52	6·22	·57	6·18	·33
	23·82	1·55	24·08	1·45	23·64	1·44
20–24 . .	6·94	·61	8·04	·69	7·84	·36
	24·80	1·92	28·46	1·87	26·47	1·35
25–29 . .	6·00	·68	7·80	·42	8·27	·76
	19·52	1·91	22·31	1·31	22·88	1·60
30–39 . .	7·05	1·01	8·24	·63	7·59	·71
	20·62	2·81	23·44	1·89	21·12	2·28
40–49 . .	8·44	1·80	9·51	·88	6·95	1·32
	22·12	4·59	20·42	2·76	15·41	3·81
50–69 . .	12·59	4·66	8·96	3·51	12·53	4·84
	26·85	10·71	19·51	6·50	28·20	10·15

TABLE XXIV.—*Females, single and widowed,* 1923–27.—*The sickness rates of workers in the cardroom expressed as a percentage of the similar rates of other groups (females) of cotton operatives* (1) *for all causes of sickness less particular respiratory causes,* (2) *for particular respiratory causes.*

Age Group.	Rates for Workers in the Cardroom as percentage of rates for ring spinners and allied workers.				Rates for Workers in the Cardroom as percentage of rates for winders, reelers and allied workers.			
(Age last birthday at beginning of year of exposure)	All Causes less Respiratory.		Respiratory Causes.		All causes less Respiratory.		Respiratory Causes.	
	Days of Sickness.	Number of Claims.	Days of Sickness.	Number of Claims.	Days of Sickness.	Number of Claims.	Days of Sickness.	Number of Claims.
16–19 ..	96	99	91	107	96	101	158	108
20–24 ..	86	87	88	103	89	94	169	142
25–29 ..	77	87	162	146	73	85	89	119
30–39 ..	86	88	160	149	93	98	142	123
40–49 ..	89	108	205	166	121	144	136	120
50–69 ..	141	138	133	165	100	95	96	106

TABLE XXV.—*Females, single and widowed, 1923–27.—Disablement rates.—The number of days of disablement per person-year of exposure and the number of claims per 100 person-years of exposure for* (1) *all causes of disablement less particular respiratory causes and* (2) *particular respiratory causes, amongst the three main occupational groups in spinning mills.*

Age Group.	Workers in the Cardroom.		Ring Spinners and Allied Workers.		Winders, Reelers, and Allied Workers.	
(Age last birthday at beginning of year of exposure).	Number of days of disablement per person-year of exposure. Number of claims per 100 person-years of exposure.		Number of days of disablement per person-year of exposure Number of claims per 100 person-years of exposure.		Number of days of disablement per person-year of exposure. Number of claims per 100 person-years of exposure.	
(1)	All Causes less Respiratory. (2)	Respiratory Causes. (3)	All Causes less Respiratory. (4)	Respiratory Causes. (5)	All Causes less Respiratory. (6)	Respiratory Causes. (7)
16–19 ..	·77	·14	·46	·19	1·00	·08
	·80	·21	·71	·07	1·14	·29
20–24 ..	2·94	·28	2·26	·52	3·46	·04
	1·92	·22	1·97	·38	2·59	·10
25–29 ..	4·13	·44	4·79	·35	2·34	·06
	1·90	·32	2·66	·28	2·61	·11
30–39 ..	5·88	·44	4·09	59	3·93	·12
	2·70	·35	3·03	·58	2·94	·15
40–49 ..	8·60	2·20	6·23	·09	5·76	6·13
	3·95	1·16	3·64	·17	4·51	3·43
50–69 ..	25·37	8 34	7·61	8·70	28·60	2·64
	10·37	4 28	5·01	3·76	11 20	1·54

TABLE XXVI.—*Females, single and widowed,* 1923–27.—*The average duration of each sickness claim* * *(first* 26 *weeks of incapacity) from* (1) *all causes of sickness less particular respiratory diseases and* (2) *particular respiratory diseases, amongst the occupational groups in spinning mills. In days.*

Age Group.	16–19		20–24		25–29		30–39		40–49		50–69	
(Age last birthday at beginning of year of exposure).	All Causes less Respiratory.	Respiratory Causes	All Causes less Respiratory.	Respiratory Causes	All Causes less Respiratory.	Respiratory Causes.	All Causes less Respiratory.	Respiratory Causes.	All Causes-less Respiratory.	Respiratory Causes.	All Causes less Respiratory.	Respiratory Causes
Workers in the cardroom ..	25	33	28	32	31	35	34	36	38	39	47	44
Ring Spinners and allied workers ..	26	39	28	37	35	32	35	33	47	32	46	54
Winders, reelers and allied workers ..	26	23	30	27	36	47	36	31	45	35	44	48
Cardroom Workers as percentage of ring spinners etc	*96*	*85*	*100*	*86*	*89*	*109*	*97*	*109*	*81*	*122*	*102*	*81*
Cardroom Workers as percentage of winders, reelers etc.	*96*	*143*	*93*	*119*	*86*	*74*	*97*	*116*	*84*	*111*	*107*	*92*

* *Vide* footnote to Table XIV.

Women, Married.

Sickness and Disablement rates from all causes of illness and from respiratory causes.—Table XXVII shows the sickness rates for married women from all causes of illness. As with the single women, the cardroom workers have a better experience than the other two occupational groups, at least up to age 50. After that age, when compared with the spinners, they have a heavier rate of sickness. In disablement (Table XXVIII) taking into account the small numbers exposed to risk, no significant difference in the three sets of rates is apparent. When the sickness is analysed into the two cause groups, respiratory and non-respiratory (Tables XXIX–XXXIII and fig. (iii)) it is seen that up to age 50 the married women in the cardroom have only about 80 to 90 per cent. of the sickness of the ring spinners from the *non-respiratory causes.* At ages 50–69 they have some excess of these non-respiratory forms of illness. *From respiratory causes* they suffer less in the first years of exposure, 20–24, slightly more at ages 25–29, less again at ages 30–39, and considerably more after age 40 is reached. Compared with the second group, the winders and reelers, the married cardroom workers have less non-respiratory illness throughout working life and less respiratory illness except in the two age groups 30–39 and 40–49

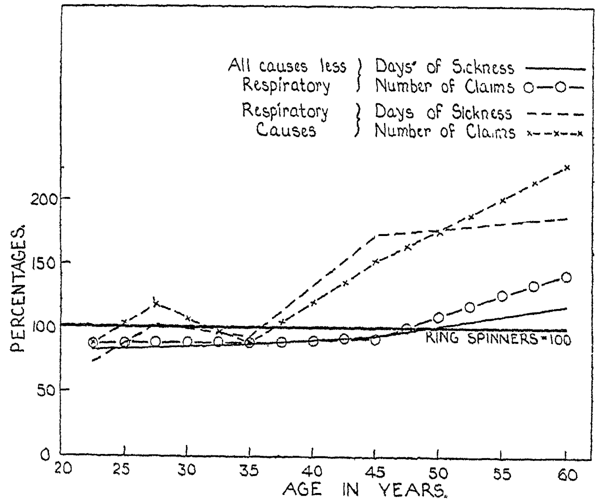

Fig. (iii).

1923–27. Sickness rates found for Cardroom Workers, FEMALES, married, (days of sickness per person-year and number of claims per 100 person-years), expressed as percentages of the rates found for Ring Spinners and Allied Workers.

Amongst the single women in the cardroom an excess of respiratory illness, it will be remembered, was observed after age 25. Judging by the comparison with the larger control group here, the spinners, the married women in the cardroom show no greater incidence of these diseases as early in life as this, and it is not until age 40 is reached that an excess is apparent. Possibly a break in their exposure to risk in the first years of married life may delay the onset of the respiratory illnesses. This excess found at the older ages, is, as with the single women, certainly due rather to an abnormal number of claims being made and not to an exceptional (average) length of claim (Table XXXIV). The disablement rates are based upon too few lives to allow discussion.

Consideration of the elimination of the incapacitated from the cardroom.—It was shown for the men (pp. 44–45, Table XVII) that there was probably an elimination of workers from the cardroom whose health was impaired by its environment, or who found that they were unable to work there A similar investigation has been made for the women, single and married, and the results are given in Tables XXXV and XXXVI The "ex-cardroom" group consists of those workers who stated on the questionnaire relating to the occupations that they were not in a cardroom during 1923–27 but had once worked there. Comparing these workers (single women—Table XXXV) with the cardroom workers it is seen that they have appreciably higher rates from all causes less respiratory diseases in every age group except the last. This is similar to the result found for the men and suggests again that amongst those who have left an employment there tend to be congregated those who left because of general unfitness—apart from any environmental causes. From respiratory causes they have also higher rates than the cardroom workers in most of the age groups, rates which are therefore, as a whole, still higher than those for spinners or winders and reelers. In other words single women who have ever worked in the cardroom show a considerable excess of respiratory illness—either because there is an elimination of persons whose health has been damaged by the environment of the cardroom, or because persons with bronchitic and asthmatic tendencies find work in its atmosphere uncongenial or impossible and thus tend to be found in the "ex-cardroom" group. For married women this selective effect is not so apparent (as would be expected since married women would tend to move in and out of employment more readily and for more reasons other than health than single women). The rates in their case from all causes less respiratory diseases do not differ very significantly between the cardroom and the ex-cardroom workers. The rates for respiratory causes are, taken as a whole, at least as high in the two groups.

TABLE XXVII.—*Females, married,* 1923–27.—*The* SICKNESS *experience from all causes.*

Workers in the Cardroom.			Ring Spinners and Allied Workers.				Winders, Reelers and Allied Workers.			
Person-years of exposure to risk.	Total duration of sickness in days	Number of days of sickness per person-year of exposure.	Person-years of exposure to risk.	Total duration of sickness in days.	Number of days of sickness per person-year of exposure	Card-room Workers as percentage of these Ring Spinners and Allied Workers.	Person-years of exposure to risk	Total duration of sickness in days	Number of days of sickness per person-year of exposure	Card-room Workers as percentage of these Winders, Reelers and Allied Workers.
3,404·5	60,999	17·92	1,238·5	27,680	22·35	80	341·0	6,604	19·37	93
7,487·5	109,349	14·60	1,929·0	32,934	17·07	86	734·0	12,366	16·85	87
12,980·5	184,184	14·19	3,558·0	58,328	16·39	87	1,199·5	16,983	14·16	100
5,633·0	81,394	14·45	987·5	14,106	14·28	101	438·5	7,587	17·30	84
2,476·0	48,897	19·75	266·0	4,000	15·04	131	189·0	3,953	20 92	94
9,237			2,386				928			

ABLE XXVIII.—*Females, married,* 1923–27.—*The* DISABLEMENT *experience from all causes.*

Workers in the Cardroom.			Ring Spinners and Allied Workers.			Winders, Reelers and Allied Workers.		
Person-years of exposure to risk.	Total duration of disablement in days.	Number of days of disablement per person-year of exposure.	Person-years of exposure to risk.	Total duration of disablement in days.	Number of days of disablement per person-year of exposure.	Person-years of exposure to risk.	Total duration of disablement in days.	Number of days of disablement per person-year of exposure.
2,998·5	8,098	2·70	1,101·5	3,743	3·40	292·5	1,291	4·41
6,488·5	16,401	2·53	1,618·5	3,542	2·19	613·0	1,371	2·24
11,510·0	59,159	5·14	3,013·0	15,994	5·31	1,033·5	6,567	6·35
5,267·5	43,188	8·20	912·0	8,451	9·27	402·0	2,893	7·20
2,381·0	67,226	28·23	252·5	6,774	26·83	176·0	4,757	27·03

TABLE XXIX.—*Females, married,* 1923–27.—*The number of person-years of exposure to risk, the duration of Sickness suffered and the number of claims made from* (1) *all causes of sickness less particular respiratory causes and* (2) *particular respiratory causes, amongst the three main occupational groups in spinning mills.*

Age Group.	Workers in the Cardroom.			Ring Spinners and Allied Workers.			Winders, Reelers and Allied Workers.		
(Age last birthday at beginning of year of exposure).	Person-years of exposure to risk.	Total duration of Sickness in days. Total number of claims made.		Person-years of exposure to risk.	Total duration of Sickness in days. Total number of claims made		Person-years of exposure to risk.	Total duration of Sickness in days. Total number of claims made	
		All Causes less Respiratory.	Respiratory Causes.		All Causes less Respiratory	Respiratory Causes.		All Causes less Respiratory.	Respiratory Causes.
20–24	3404·5	56,922	4,077	1238·5	25,608	2,072	341·0	6,138	466
		1,628	113		678	48		166	12
25–29	7487·5	101,332	8,017	1929·0	30,909	2,025	734·0	10,958	1,408
		2,752	236		818	52		272	23
30–39	12980·5	167,092	17,092	3558·0	53,169	5,159	1199·5	15,925	1,058
		4,318	460		1,374	147		407	31
40–49	5633 0	68,069	13,325	987·5	12,743	1,363	438·5	6,771	816
		1,712	345		323	40		151	15
50–69	2476·0	35,522	13,375	266·0	3,233	767	189·0	2,832	1,121
		828	297		62	14		60	23
Total Number of *persons* exposed ..	9,237			2,386			928		

TABLE XXX.—*Females, married,* 1923–27.—*The number of person-years of exposure to risk, the duration of Disablement suffered, and the number of claims made from* (1) *all causes of disablement less particular respiratory causes and* (2) *particular respiratory causes, amongst the three main occupational groups in spinning mills.*

Age Group.	Workers in the Cardroom.			Ring Spinners and Allied Workers			Winders, Reelers and Allied Workers.		
(Age last birthday at beginning of year of exposure).	Person-years of exposure to risk.	Total duration of disablement in days. Total number of claims made.		Person-years of exposure to risk.	Total duration of disablement in days Total number of claims made		Person-years of exposure to risk.	Total duration of disablement in days. Total number of claims made.	
		All Causes less Respiratory.	Respiratory Causes.		All Causes less Respiratory	Respiratory Causes		All Causes less Respiratory	Respiratory Causes.
20–24	2998·5	7,650 113	448 11	1101·5	3,306 45	437 6	292·5	1,291 12	— —
25–29	6488·5	14,585 169	1,816 18	1618·5	3,115 36	427 4	613·0	1,159 14	212 4
30–39	11510·0	52,662 406	6,497 60	3013·0	13,984 130	2,010 16	1033·5	6,167 39	400 5
40–49	5267·5	35,783 222	7,405 51	912·0	5,908 41	2,543 10	402·0	2,885 25	8 1
50–69	2381·0	44,982 228	22,244 107	252·5	6,629 32	145 3	176·0	3,156 18	1,601 9

TABLE XXXI.—*Females, married,* 1923–27. *Sickness rates.—The number of days of sickness per person-year of exposure and the number of claims per* 100 *person-years of exposure from* (1) *all causes of sickness less particular respiratory causes and* (2) *particular respiratory causes, amongst the three main occupational groups in spinning mills.*

Age Group.	Workers in the Cardroom.		Ring Spinners and Allied Workers.		Winders, Reelers and Allied Workers.	
(Age last birthday at beginning of year of exposure)	Number of days of sickness per person-year of exposure Number of claims per 100 person-years of exposure.		Number of days of sickness per person-year of exposure. Number of claims per 100 person-years of exposure.		Number of days of sickness per person-year of exposure Number of claims per 100 person-years of exposure.	
(1)	All Causes less Respiratory (2)	Respiratory Causes. (3)	All Causes less Respiratory (4)	Respiratory Causes. (5)	All Causes less Respiratory. (6)	Respiratory Causes (7)
20–24 . .	16·72	1·20	20·68	1·67	18·00	1·37
	47·82	3·32	54·74	3·88	48 68	3·52
25–29 . .	13·53	1·07	16 02	1·05	14·93	1·92
	36·75	3·15	42·41	2·70	37·06	3·13
30–39 . .	12·87	1·32	14 94	1·45	13·28	·88
	33·27	3·54	38·62	4·13	33·93	2·58
40–49 . .	12·08	2·37	12·90	1·38	15·44	1·86
	30·39	6·12	32·71	4·05	34·44	3·42
50–69 . .	14·35	5·40	12·15	2·88	14·98	5·93
	33·44	12·00	23·31	5·26	31·75	12·17

TABLE XXXII.—*Females, married, 1923–27.—The sickness rates of workers in the cardroom expressed as a percentage of the similar rates of other groups (females) of cotton operatives (1) for all causes of sickness less particular respiratory causes, (2) for particular respiratory causes.*

Age Group.	Rates for Workers in the Cardroom as percentage of rates for ring spinners and allied workers.				Rates for Workers in the Cardroom as percentage of rates for winders, reelers and allied workers.			
	All Causes less Respiratory.		Respiratory Causes.		All Causes less Respiratory.		Respiratory Causes.	
	Days of Sickness.	Number of Claims.	Days of Sickness.	Number of Claims	Days of Sickness.	Number of Claims.	Days of Sickness.	Number of Claims.
20–24 ..	81	87	72	86	93	98	88	94
25–29 ..	84	87	102	117	91	99	56	101
30–39 ..	86	86	91	86	97	98	150	137
40–49 ..	94	93	172	151	78	88	127	179
50–69 ..	118	143	188	228	96	105	91	99

TABLE XXXIII.—*Females, married,* 1923–27.—*Disablement rates.—The number of days of disablement per person-year of exposure and the number of claims per* 100 *person-years of exposure for* (1) *all causes of disablement less particular respiratory causes and* (2) *particular respiratory causes, amongst the three main occupational groups in spinning mills.*

Age Group.	Workers in the Cardroom		Ring Spinners and Allied Workers.		Winders, Reelers and Allied Workers.	
(Age last birthday at beginning of year of exposure.)	Number of days of disablement per person-year of exposure. Number of claims per 100 person-years of exposure.		Number of days of disablement per person-year of exposure. Number of claims per 100 person-years of exposure.		Number of days of disablement per person-year of exposure. Number of claims per 100 person-years of exposure.	
(1)	All Causes less Respiratory. (2)	Respiratory Causes. (3)	All Causes less Respiratory. (4)	Respiratory Causes. (5)	All Causes less Respiratory. (6)	Respiratory Causes. (7)
20–24 . .	2·55	·15	3·00	·40	4·41	—
	3·77	·37	4·09	·54	4·10	—
25–29 . .	2·25	·28	1·92	·26	1·89	·35
	2·60	·28	2·22	·25	2·28	·65
30–39 . .	4·58	·56	4·64	·67	5·97	·39
	3·53	·52	4·31	·53	3·77	·48
40–49 . .	6·79	1·41	6·48	2·79	7·18	·02
	4·21	·97	4·50	1·10	6·22	·25
50–69 . .	18·89	9·34	26·25	·57	17·93	9·10
	9·58	4·49	12·67	1·19	10·23	5·11

TABLE XXXIV.—*Females, married,* 1923–27.—*The average duration of each sickness claim* * (*first* 26 *weeks of incapacity*) *from* (1) *all causes of sickness less particular respiratory diseases and* (2) *particular respiratory diseases, amongst the occupational groups in spinning mills. In Days.*

Age Group (age last birthday at beginning of year of exposure).	20–24.		25–29.		30–39.		40–49.		50–69.	
	All Causes less Respiratory.	Respiratory Causes.	All Causes less Respiratory.	Respiratory Causes.	All Causes less Respiratory.	Respiratory Causes	All Causes less Respiratory.	Respiratory Causes.	All Causes less Respiratory.	Respiratory Causes.
Workers in the cardroom . .	35	36	37	34	39	37	40	39	43	45
Ring spinners and allied workers . .	38	43	38	39	39	35	39	34	52	55
Winders, reelers and allied workers . .	37	39	40	61	39	34	45	54	47	49
Cardroom workers as percentage of ring spinners, etc	*92*	*84*	*97*	*87*	*100*	*106*	*103*	*115*	*83*	*82*
Cardroom workers as percentage of winders, reelers, etc. . .	*95*	*92*	*93*	*56*	*100*	*109*	*89*	*72*	*91*	*92*

* *Vide* footnote to Table XIV.

TABLE XXXV.—*Females, single and widowed,* 1923–27.—*Sickness amongst workers not in the cardroom during* 1923–27, *but who had previously worked in that room (ex-cardroom workers), compared with the sickness of cardroom workers in* 1923–27.

Age Group.	Ex-Cardroom Workers.					Cardroom Workers.	
(Age last birthday at beginning of year of exposure).	Person-years of exposure to risk.	Total duration of Sickness in days. Total number of claims made		Number of days of Sickness per person-year. Number of claims per 100 person-years.		Number of days of Sickness per person-year. Number of claims per 100 person-years.	
		All Causes less Respiratory.	Respiratory Causes.	All Causes less Respiratory.	Respiratory Causes	All Causes less Respiratory	Respiratory Causes.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
16–19 ..	370·0	4,214	346	11·39	·94	5·95	·52
		138	9	37·30	2·43	23·82	1 55
20–24 ..	515·0	4,366	108	8·48	·21	6·94	·61
		158	5	30·68	·97	24·80	1·92
25–29 ..	570·0	4,994	652	8·76	1·14	6·00	·68
		152	15	26·67	2·63	19 52	1·91
30–39 ..	708·0	6,576	1,470	9·29	2·08	7·05	1·01
		176	51	24·86	7·20	20·62	2·81
40–49 ..	309·5	3,205	1,048	10·36	3·39	8·44	1·80
		80	28	25·85	9·05	22·12	4·59
50–69 ..	219·0	2,342	1,081	10·69	4·94	12·59	4·66
		46	20	21·00	9·13	26·85	10·71
Total number of *persons* exposed ..	717						

TABLE XXXVI.—*Females, married,* 1923–27.—*Sickness amongst workers not in the cardroom during* 1923–27, *but who had previously worked in that room (ex-cardroom workers), compared with the sickness of cardroom workers in* 1923–27.

Age Group.	Ex-Cardroom Workers.					Cardroom Workers.	
(Age last birthday at beginning of year of exposure).	Person-years of exposure to risk.	Total duration of Sickness in days. Total number of claims made.		Number of days of Sickness per person-year Number of claims per 100 person-years.		Number of days of Sickness per person-year. Number of claims per 100 person-years.	
		All Causes less Respiratory.	Respiratory Causes.	All Causes less Respiratory.	Respiratory Causes.	All Causes less Respiratory.	Respiratory Causes.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
20–24 ..	117·0	1,787	159	15·27	1·36	16·72	1·20
		50	6	42·73	5·12	47·82	3·32
25–29 ..	361·5	5,749	312	15 90	·86	13·53	1·07
		131	11	36·24	3·04	36·75	3·15
30–39 ..	635·5	8,794	1,127	13·84	1·77	12·87	1·32
		223	23	35·09	3·62	33·27	3·54
40–49 ..	327·0	3,698	456	11·31	1·39	12·08	2·37
		83	10	25·38	3·06	30·39	6·12
50–69 ..	155·0	2,177	683	14·05	4·41	14·35	5·40
		39	12	25·16	7·74	33·44	12·00
Total number of *persons* exposed ..	536						

Unemployment and Rates of Pay.

As was pointed out for the men, these differences in the sickness rates for women, married and single, from respiratory complaints cannot be easily explained in terms of any other factors except that of the working environment. There is very little difference in wage levels or amount of unemployment between the three occupational groups in 1923–27. The cardroom workers and ringroom workers are on approximately the same level of income —for a full working week the *average* wage would be about thirty shillings. The average wage in the winding and reeling department would be somewhat higher—about thirty-three shillings. Such differences are obviously negligible, as also would be the differences in amount of short-time, since each department is dependent upon the other.

Discussion of the Results.

It was pointed out in the section dealing with the men that evidence that disability was still being produced by the cardroom environment (*i.e.*, since the introduction of localized exhaust ventilation) was lacking. The fact that there is some excess of respiratory complaints amongst women, though a much slighter excess than that found for the men, suggests either (*a*) considerably less dust is needed to impair health than that evolved under the old processes of stripping and grinding, since the women never are or were exposed to the maximum found near to the carding engines, but only to that blown across to the other side of the cardroom ; or (*b*) floating cotton fibre to which the women are considerably exposed is a principal or contributory factor. This inquiry cannot prove the truth of either of these suggestions, but they are put forward to show that the women do afford some evidence that it is not necessary to have such exposure to dust as existed for the men before 1912 for damage to health to be caused. It is possible that the less exposure (*i.e.*, less than the men) which the women experienced before 1912 is sufficient. Whether the present environment for women is deleterious cannot be proved, as with the men, until a population exists which has been exposed for a considerable number of years to modern conditions only.

Summary of Main Points and Conclusions.

(1) For a considerable number of years complaints have been made by the representatives of cotton cardroom operatives in Lancashire that these workers suffer acutely from respiratory diseases, as a result of the environment in which they have to work. These led in 1927 to the appointment of a Departmental Committee of inquiry, one of the terms of reference being to report upon the Sickness rates of cardroom operatives in comparison with those of the general population in the same localities. It was found

impracticable to secure sickness statistics for such a general population and other cotton operatives in the same spinning mills were substituted as the comparative group (pp. 5–6).

(2) A preliminary study of the occupational death rates for men in the years 1921–23, published by the Registrar-General for England and Wales, shows that strippers and grinders (*i.e.*, the cardroom workers who are exposed to dust to the maximum extent), other workers in the cardroom, and blowing-room hands all have, in comparison with other operatives in the cotton industry, and in comparison with all males (occupied and retired) in England and Wales, high death rates from respiratory diseases, the unfavourable position being most pronounced for the strippers and grinders. The latter also compare unfavourably at the older ages, with the general population of the towns in which they live (pp. 12–17 and Tables I, II and III). Circulatory and allied diseases also seem to be important for cotton workers, but for the cardroom hands at least not nearly so acutely as the respiratory group of illnesses (with the exception of tuberculosis, the rates for which are low) (pp. 17–19 and Table IV).

(3) The *ad hoc* sickness investigation here reported corroborates for the men the results shown by the occupational death rates. The conclusions that follow are based upon the short-period sickness statistics only, *i.e.*, the first 26 weeks of illness. The disablement rates, *i.e.*, illness after the first 26 weeks were unreliable owing to the small numbers involved. From all causes of sickness the strippers and grinders suffer approximately the same up to age 30 as the comparative group working in the ring-room and warehouse. After that age they have some excess of illness. When however this sickness experience is divided into non-respiratory and respiratory causes it is found that strippers and grinders and other cardroom workers have somewhat *less* sickness than male workers in the ring-room and warehouse from *all causes of sickness excluding a group of respiratory diseases.* On the other hand from *these particular respiratory diseases* they have, after age 30, a pronounced excess of illness, their rates being two to three times as high as the rates found for the workers in the ring-room and warehouse. Between the cardroom workers and the blowing-room and cotton room operatives very little discrepancy is found. This latter group is also involved in the preliminary cleansing processes and is subject to a transference of workers who have been in the cardroom. Whether their higher respiratory rates are due to the inclusion amongst them of cardroom workers who have left the cardroom with damaged health or to their own environment being detrimental to health cannot be proved. (pp. 29–32 and Tables VII, IX, XI and XII, and fig. I).

(4) Figures for disablement (long-period incapacity after the first 26 weeks of sickness) are not reliable for populations as small

as those here exposed to risk. Broadly they seem to confirm the conclusion reached from the more stable short-period sickness rates (pp. 29–32 and Tables VIII, X and XIII).

(5) The excess of respiratory illness amongst the male cardroom workers is due to a *greater number of claims* being made by these workers and *not* to abnormally long periods of such incapacity. On the whole the average duration of their illness from such causes is somewhat shorter than that of the ringroom and warehouse workers. This larger number of claims is derived both from an actually larger number of *persons* claiming and also from an excess of persons making repeated claims for such reasons (pp. 32 and 41 and Tables XIV, XV and XVI).

(6) A comparison was attempted between the men working in towns mainly confined to spinning coarse and fine counts, but the material was insufficient to prove whether there existed any difference in incidence of illness (pp. 48–49).

(7) The sickness experience both of single and of married women (treated separately) showed that the female cardroom workers had up to age 50, somewhat *less* incapacity than ring spinners and than winders and reelers from *all causes of illness.* When the sickness was divided into respiratory and non-respiratory forms, single women showed an excess of respiratory sickness after age 25, and married women a similar excess after age 40. This excess was considerably less than that found for the men, being rather in the neighbourhood of 60 to 75 per cent. over the spinners' rates. This excess was derived more from a greater number of claims being made than from an abnormal length of incapacity though both factors contributed to the higher incidence (pp. 53–65 and Tables XIX to XXXIV, and Figs 2 and 3).

(8) A consideration of workers, male and female, who at one time worked in the cardroom but who were not in the cardroom during the period of inquiry (but who remained members of the Approved Society under consideration), showed that these workers likewise have unduly high rates from respiratory illness. This suggests some elimination from the cardroom of workers whose health has been damaged by its environment, or of workers with bronchitic tendencies who find its conditions unsuitable for them (pp. 44–45 and p. 65 and Tables XVII, XXXV and XXXVI).

(9) The excess of respiratory illness found amongst the cardroom workers cannot easily be explained by any other factors except environment (pp. 49–50 and p. 76).

(10) Since 1912, when localized exhaust ventilation and vacuum for stripping were being introduced, conditions in the cardroom have been materially altered. The point that arises is whether present day conditions are such as to cause any excess of respiratory disease, or whether the excess found at the older ages is due only to the very dusty conditions in which these older operatives once worked. Evidence that suggests that present day conditions

may be unfavourable to health is (1) the blowing-room hands show an excess of such diseases and the dust does not reach its maximum there; but this evidence is weakened by the undoubted transference of cardroom workers to the blowing room, and the possible transference of those already suffering from respiratory complaints; (2) the women show some excess of respiratory complaints and these workers never were exposed to the full dust of the carding machines, but only to what was blown from the machines to the other side of the room. On the other hand it may be that the floating cotton fibre is an agent in the production of these diseases and to this the women are considerably exposed.

There is no evidence of an excess of respiratory illness amongst the younger workers who have only worked under the modern conditions (except perhaps, in the higher rates of the single women aged 25–29). On the other hand, this is not conclusive that modern conditions do not cause respiratory illness since it may be that some years' exposure is necessary before the effect of the environment will be shown in absence from work due to illness (it must be remembered, too, that the numbers of men exposed to risk at the earlier ages are small so that their rates may be unreliable).

If this is true, that some years' exposure to dust *is* necessary to produce respiratory illness of the type found to be excessive amongst these older workers, then sickness statistics, such as are here set out, cannot prove whether modern conditions are detrimental to health or not. For at present there is no body of workers who have worked only under the modern conditions for a considerable number of years. If prolonged exposure is a factor, then ten to fifteen years must elapse before there will exist such a population of operatives who have been exposed to modern conditions for sufficiently long for its effect upon their health to be seen in sickness statistics.

It seems evident that conditions in the cardroom before localized exhaust ventilation and vacuum for stripping were introduced were distinctly unfavourable to health, both men and women being affected. Such extreme conditions no longer exist and it is to be hoped that the injurious effect upon health has changed with the change in environment. In the absence of positive evidence that this is so, the reduction of the operatives' exposure to dust and fibre, to the maximum extent possible, is obviously desirable.

APPENDIX

THE USE OF RESPIRATORS IN THE CARDROOM.

Towards the end of 1927 the Insurance Section of the Association of Card, Blowing and Ring Room Operatives offered to supply, free of charge, a respirator to any of its members who applied for one These respirators were made of soft vulcanised rubber shaped to fit over the nose and mouth dust-tightly, and were fitted with dry cotton disc filters to catch the dust and fibre that might otherwise be inhaled. By November, 1928, some 1,100 had been issued. When the respirator was sent to the operative applying he was asked if, after wearing it for about four weeks, he would write and state whether he felt any benefit from it. Only just over one hundred such letters were received all of which, with one exception, were definitely in favour of it and many regretted that they had not had such a device when they first began to work in the cardroom. The single exception was a man of 64 years of age who found breathing through it too difficult for him There were a certain number of complaints, from those who thought it of value, that it made them too hot to be comfortable. It is impossible to know whether these replies are representative of the general opinion. Less than 10 per cent of those applying for respirators made any later reply, and it may be that the more enthusiastic would tend to write and those who derived no benefit would not do so but merely cease to use it. A test has been made to see whether any benefit is shown in *recorded* sickness. The date of issue of the respirator was observed for each man and the sickness he experienced in the twelve months before issue compared with that he suffered in the twelve months after issue. Those operatives were taken to whom respirators were issued between October, 1927, and November, 1928, of whom there were 1,094 (excluding two or three who were chronically disabled at the time the respirator was sent to them and never recovered to wear it). Thus, for the whole number, the sickness in the twelve months before issue lies between October, 1926, and November, 1928, and the sickness after issue between October, 1927, and November, 1929. (In the case of exits before 12 months had elapsed *after* issue of respirator the exposure *before* issue was made of equal length with that between date of issue and date of exit). The age distribution remains the same in either case—except, of course, that in the after issue period the population is a year older. The population is too small to allow division into age groups and has therefore been used as a whole. Sickness has been divided into the two groups used throughout the report —respiratory and non-respiratory*.

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* Only the sickness experience has been used. The disablement experience is obviously biassed since the permanently disabled will not have applied for respirators not being at work, so that the disablement in the year before issue must be less than that in the year after ; for a number of persons will become permanently disabled soon after issue and are not counterbalanced by persons permanently disabled in the year before issue.

Out of the 1,094 operatives 730 had no sickness at all over the two year period , the remaining 364 were ill either in the first year or second year or in both, one or more times. The amount of sickness suffered was as follows :—

	In year previous to issue of respirator.		In year after issue of respirator.		Year after issue as per cent. of year before issue.	
	Non-respiratory causes	Respiratory causes.	Non-respiratory causes	Respiratory causes.	Non-respiratory causes.	Respiratory causes.
Days of Sickness experienced	5,384	3,546	4,701	2,977	—	—
No. of Claims made ..	203	110	186	100	—	—
Days of Sickness per person	4·9	3·2	4·3	2 7	88	84
No. of Claims per 100 persons	18·6	10·1	17·0	9·1	91	90

It will be seen that there was a fall in sickness incidence in the year after issue of the respirators but that the fall is just as great for non-respiratory causes as for respiratory causes. The days of sickness per person for non-respiratory causes are in the first year 4 9 and in the second year 4·3 , the value in the year *after* issue is 88 per cent. of the value in the year *before* issue. For respiratory causes the second year is 84 per cent. of the first, the days per person being 3·2 and 2·7. The claims in the second year are 91 per cent of those in the first year for non-respiratory causes, the rates being 18·6 and 17·0 per 100 persons, and 90 per cent. for respiratory causes where the rates are 10·1 and 9·1 per 100 persons. The average length of a claim was 27 days for non-respiratory causes and 32 days for respiratory causes in the first year, values which fell to 25 days and 30 days in the second year. Thus the slight fall that has taken place in the incidence of respiratory diseases since the issue of respirators does not differ significantly from the fall that has taken place in all other diseases which cannot have been affected by the introduction of the respirator. In other words this, admittedly slight, test does not show that respirators have affected the incidence of respiratory sickness. On the other hand the trial has been a short one and longer experience might show that respirators were of value—at any rate to workers whose health had not been already affected. The question is not an easy one to test since so many factors affect a sickness rate, *e.g.*, in this case the influenza epidemic of 1929 might have some influence on the results. The operatives' letters show that at least a section of them quite definitely do think their health *is* improved and their working-day eased by the use of some such device. Better evidence of the respirator's effect would have been supplied if this group to whom respirators were issued could have been compared with a cardroom group who never used such. To get such a population of equal age distribution would entail considerable labour and then be open to the objection that it would not be known whether these workers actually had obtained some form of respirators from other sources (as is known to have been done in some cases). For this reason the change in incidence of non-respiratory diseases was used for comparison rather than the change in incidence of both groups of diseases in another population This test certainly lacks positive evidence of the respirators conferring benefit, but the evidence presented is too slight to be taken as conclusive.

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C.—TEXTILE INDUSTRIES.

No. 7.—Individual Differences in Output in the Cotton Industry.

No. 8.—Some Observations on Bobbing Winding.

No. 9.—A Study of Output in Silk Weaving during the Winter Months.

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† A short account of the principal practical conclusions reached up to 1924 will be found in Report No. 27 (Results of Investigations in Certain

No. 17.—An Analysis of the Individual Differences in the Output of Silk-Weavers.
No. 20.—A Study of Efficiency in Fine Linen Weaving.
No 21 —Atmospheric Conditions in Cotton Weaving.
No. 23 —Variations in Efficiency in Cotton Weaving.
No. 37 —Fan Ventilation in a Weaving Shed.
No. 40.—The Effect of Eyestrain on the Output of Linkers in the Hosiery Industry.
No. 48.—Artificial Humidification in the Cotton Weaving Industry. Its Effect upon the Sickness Rates of Weaving Operatives.
*No. 49.—On the Relief of Eyestrain amongst Persons Performing very Fine Work.

D.—BOOT AND SHOE INDUSTRY.

No. 10.—Preliminary Notes on the Boot and Shoe Industry.
No. 11.—Preliminary Notes on Atmospheric Conditions in Boot and Shoe Factories.
*No. 25.—Two Contributions to the Study of Rest Pauses in Industry
*No. 26.—On the Extent and Effects of Variety in Repetitive Work.
*No. 35.—A Physiological Study of the Ventilation and Heating in Certain Factories

E.—POTTERY INDUSTRY.

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No. 24.—A Comparison of Different Shift Systems in the Glass Trade.

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J.—LIGHT REPETITION WORK.

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K.—MUSCULAR WORK.

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No. 55.—A Study of Personal Qualities in Accident Proneness and Proficiency.

PAPERS BASED ON RESULTS OBTAINED FOR THE BOARD OR ITS RELATED COMMITTEES AND PUBLISHED IN SCIENTIFIC JOURNALS.

Bedford, T. (1922) : The Ideal Work Curve.—*J. Ind. Hyg.*, **4,** 6.

Bedford, T. (1928) : Some effects of Atmospheric Conditions on the Industrial Worker.—*J. Ind. Hyg* , **10,** 10.

Burnett I., and Pear, T. H. (1925) : Motives in Acquiring Skill.—*Brit. J. Psych* , **16,** 2.

Cathcart, E. P. (1928) : *The Human Factor in Industry.* London.

Cathcart, E. P., Bedale, E. M., and McCallum, G. (1923) : Studies in Muscle Activity.—I. The Static Effect.—*J. Physiol.*, **57,** 3 & 4.

Cripps, L. D., Greenwood, M., and Newbold, E. M. (1923) : A Biometric Study of the Inter-relations of Vital Capacity, Stature Stem Length and Weight in a Sample of Healthy Male Adults —*Biometrika*, **14,** 3 & 4.

Culpin, M. (1928) : A Study of the Incidence of the Minor Psychoses—their Clinical and Industrial Importance.—*Proc. Roy. Soc. Med.*, **21,** 419. (*Sect. Psychiat.*, p. 13) and *Lancet*, 4th Feb., 1928.

Culpin, M. and Smith, M. (1928) : Sickness Absenteeism : a preliminary study.—*Brit. M. J.* 21st July, 1928.

Dickinson, S. (1928) : The Dynamics of Bicycle Pedalling.—*Proc. Roy. Soc.* B. **103,** 225.

Farmer, E. (1922) : Time and Motion Study.—*J. Ind. Hyg.*, **4,** 5.

Farmer, E. (1923): Interpretation and Plotting of Output Curves.—*Brit. J. Psych.*, **13,** 3.

Farmer, E. (1927): A Group Factor in Sensory Motor Tests.—*Brit. J. Psych.*, **17,** 4

Farmer, E. (1927): Parallelism in Curves of Motor Performance.—*Brit. J. Psych.*, **17,** 4.

Farmer, E., and Chambers, E. G. (1925): Concerning the Use of the Psycho-galvanic Reflex in Psychological Experiments.—*Brit. J. Psych.*, **15,** 3.

Fraser, J. A. (1924): The Vocational Selection and Training of Operatives for the Weaving Industry.—*J. Nat. Inst Ind. Psych.*, **2,** 2.

Fraser, J. A. (1927): The Value of Stoppage Analysis with special reference to Weaving.—*J. Nat. Inst. Ind. Psych.*, **3,** 8.

Fraser, J. A. (1929): The Machine and the Worker.—*J. Nat. Inst. Ind. Psychol.* **4,** 7.

Gaw, F. (1923): The Use of Performance Tests and Mechanical Tests in Vocational Guidance.—*J. Nat Inst. Ind. Psych* , **1,** 8.

Greenwood, M., and Newbold, E. M. (1923): On the Estimation of Metabolism from Determinations of Carbon Dioxide Production and on the Estimation of External Work from the Respiratory Metabolism —*J. Hyg.*, **21,** 4.

Hambly, W. D., and McSwiney, B. A. (1922): The U-tube Manometer Test with relation to Muscular Exercise.—*Proc. Physiol. Soc.*, Oct. 21, 1922.

Hambly, W. D., Pembrey, M. S., and Warner, E. C. (1925): The Physical Fitness of Men assessed by various Methods.—*Guy's Hosp. Rep.*, Oct , 1925.

Hewitt, E. M., and Bedale, E. M. (1923): A Study of the Comparative Physiological Costs of Different Methods of Weight Carrying by Women.—*Ann. Rep. of the Chief Inspector of Factories for* 1922.

Hill, A. V. (1927): *Muscular Movement in Man.* New York.

Hill, A. V. (1927): *Living Machinery.* London.

Hill, A. V., Long, C. N. H., and Lupton, H. (1924): Muscular Exercise, Lactic Acid and the Supply and Utilisation of Oxygen —*Proc. Roy. Soc.*, B. **96,** 438; **97,** 84; **97,** 155.

Hill, A. V., and Lupton, H (1923): Muscular Exercise, Lactic Acid, and the Supply and Utilisation of Oxygen.—*Quart. J. Med* , **16,** 62.

Hill, L., Vernon, H. M., and Hargood-Ash, D. (1922): The Kata-Thermometer as a Measure of Ventilation.—*Proc. Roy. Soc.*, B. **93,** 198.

Hughes, D. E. R. (1928): A Comparative Study of Unemployed and Employed boys.—*Sociol. Rev.* **20.,** 4.

James, H. E. O., and Thouless, R. H. (1926): A Note on the Effect of Polarisation in Psycho-Galvanic Experiments.—*Brit. J. Psych.*, **17,** 1.

Langdon, J. N. and Yates, E. M. (1928): Transfer of Training in Manual Dexterity.—*Memoirs of Manchester Literary and Philosophical Society,* January.

Langdon, J. N. and Yates, E. M. (1928): An Experimental Investigation into Transfer of Training in Skilled Performances.—*Brit. J. Psychol.*, **18,** 4.

Lupton, H. (1922): Relation between External Work and Time Occupied in a Single Muscular Contraction.—*J. Physiol.*, **57,** 1 & 2.

Lupton, H. (1923): Exercise and Oxygen.—*Med. School Gaz.*, **2,** 3.

Lupton, H. (1923): An Analysis of the Effects of Speed on the Mechanical Efficiency of Human Muscular Movement.—*J. Physiol.*, **57,** 6.

MUSCIO, B. (1920): Fluctuations in Mental Efficiency.—*Brit. J. Psych.*, **10**, 4.

MUSCIO, B. (1921): Is a Fatigue Test Possible ?—*Brit. J. Psych.*, **12**, 1.

MUSCIO, B. (1921): Feeling Tone in Industry.—*Brit. J. Psych.*, **12**, 2.

MUSCIO, B. (1922): Motor Capacity with Special Reference to Vocational Guidance.—*Brit. J. Psych.*, **13**, 2.

MUSCIO, B., and SOWTON, S. M. (1923): Vocational Tests and Typewriting —*Brit. J. Psych.*, **13**, 4.

NEWBOLD, E. M. (1923): Note on Dr. Burnside's Paper on Errors of Observation.—*Biometrika*, **15**, 3 & 4.

PEAR, T. H. (1927): Repetitive Work.—*Dictionary of Industrial Administration.*

PEAR, T. H. (1927): Work, Temperament and Fatigue.—*Rep. Internal Ass. for Study of Relations and Conditions in Industry.* (Baveno), 1927.

PEAR, T. H., (1927): Recent Studies of Skilled Performance with reference to Transfer of Training.—*Nature*, 18th Jan.

PEAR, T. H., LANGDON, J N. and YATES, E. M. (1928): The Nature of Manual Dexterity and its Relation to Vocational Training.—*Nature*, 12th May, 1928.

PEAR, T. H., LANGDON. J. N. and YATES, E. M. (1928): Transfer of Training and Transference —*New Era*, June, 1928.

PEAR, T H. (1928): *Fitness for Work*, London.

PEAR. T. H. (1928): The Nature of Skill. (Presidential Address to the Psychology Section of the British Association, Glasgow.)—*J. Inst. Ind. Psychol*, **4**, 193, and Abstr. *Nature.* 8th Sept., 1928.

PEMBREY, M. S., and OTHERS (1922): Tests for Physical Fitness.—Part I.—*Guy's Hospital Reports*, Oct., 1921. Part II.—*Ibid.*, Oct., 1922.

RUSHER, E. A. (1922): The Statistics of Industrial Morbidity in Great Britain.—*J. Roy. Stat. Soc.*, **85**, 1.

SARGENT, R. M. (1926): The Relation between Oxygen Requirement and Speed in Running.—*Proc. Roy. Soc. B.*, Vol. **100**, 1926.

SMITH, MAY (1923): Practical Problems of Industrial Life.—*Ind. Welfare*, **5**, 58.

SMITH, MAY (1923): The Laundry Trade.—*Laundry Record*, **33**, 388.

SMITH, MAY (1926): Industrial Psychology.—*Article in Encyclopædia Britannica (XIIth Edition).*

SMITH, M. (1928): The Worker of the Machine.—*Trans. Machinery Users' Association.* (1927–8.)

SMITH, M. (1928): Sickness Records.—*Welfare Work*, Sept., 1928.

SMITH, M. (1928): Some Medico-psychological Problems in Industry.—*J. Neurol, and Psychopathol.* Oct., 1928.

STURT, M. (1922): A Comparison of Speed with Accuracy in the Learning Process.—*Brit. J. Psych.*, **12**, 3.

VERNON, H. M. (1921): The Influence of Atmospheric Conditions on Industrial Efficiency.—*J. State Med.*, **29**, 353.

VERNON, H. M. (1921): The Influence of Fatigue on Health and Longevity. —*J. Ind. Hyg.*, **3**, 3.

VERNON, H. M. (1922): Recent Investigation on Atmospheric Conditions in Industry.—*J. Ind. Hyg.*, **4**, 8.

VERNON, H. M. (1923): A Note on the Causes of Output Limitation.—*J. Nat. Inst. Ind. Psych.*, **1**, 5.

VERNON, H. M. (1923): Atmospheric Conditions in Potters' Shops and the Efficiency of Various Types of Drying Stoves.—*Trans. Ceramic Soc.*, 22, p. 70.

VERNON, H. M. (1923): The Causation of Industrial Accidents.—*J. Ind Hyg.*, **5,** 1.

VERNON, H. M., and BEDFORD, T. (1924): The Influence of Short Time on Speed of Production.—*J. Nat. Inst. Ind. Psych.*, **2,** 155.

VERNON, H. M. (1925): Can Laboratory Experiments on Output throw Light on Problems of Industrial Fatigue ?—*Brit. J. Psych.*, **15,** 4.

VERNON, H. M. (1925): The Kata-Thermometer as an Indicator of Radiant Heat.—*J. Nat. Inst. Ind. Psych.*, **2,** 198.

VERNON, H. M. (1925): The Work of the Tin-Plate Doubler.—*J. Nat. Inst. Ind. Psych.*, **2,** 373.

VERNON, H. M. (1926): Is Effective Temperature or Cooling Power the Better Index of Comfort ?—*J. Ind. Hyg.*, **8,** 392.

VERNON, H. M. (1927): The Elimination of Fatigue caused by Extremes of Temperature, Humidity and Dust.—*Rep. Internat. Ass. for Study of Human Relations and Conditions in Industry.* (Baveno), 1927.

VERNON, H. M. (1927): Ventilation in relation to Health.—*J. State Med.*, **34,** 683.

VERNON, H. M. (1927): The Wet Kata-thermometer as an Index of the Suitability of Atmospheric Conditions for Heavy Work.—*J. Indust. Hyg.*, **9,** 287.

VERNON, H. M., AND OTHERS (1926): Methods of Investigating Ventilation and its Effects.—*Med. Res. Council Spec. Rep. Series No.* 100.

VERNON, H. M., and BEDFORD, T. (1927): The Ventilation and Heating of Factories.—*J. Indust. Hyg.*, **9.** 51.

VERNON, H. M., and VERNON, M. D. (1927): The Physical and Physiological Effects of Radiant Heating by the Panel System.—*Proc. Physiol. Soc., J. Physiol.*, **64,** 1.

VERNON, H M. (1928) · The Fatigue of Heavy Industrial Work, and its Influence on the Health and Duration of Industrial Life —*J. State Med.* **37,** pp. 141–152.

VERNON, H. M. (1928): Accidents in Industry and the Human Factor.—*Brochure No.* 109 *of "Occupation and Health."*; *Internat. Labour Office.* pp. 1–11.

VERNON, H. M. (1928): Methods of Heating and Ventilating Schools and their Influence on Health.—*Domestic Engineering*, **48,** pp 201–206, and 231–232.

VERNON, H. M. (1929): "What are the most pressing Problems requiring Research in the Immediate Future ?"—*Report of International Industrial Relations Association.* pp. 236–245.

VERNON, H. M. (1929): The Effects of a Bonus on the Output of Men engaged in Heavy Work.—*J. Nat. Inst. Indust. Psychol.*, **4,** pp. 267–270

VERNON, H M., BEDFORD, T. and WARNER, C. G. (1928): The Influence of Various Systems of Artificial Heating on Skin Temperature.—*Proc. Physiol., Soc., J. Physiol.*, **66,** viii.

VERNON, H. M., BEDFORD, T. and WARNER, C. G. (1928): Absenteeism in Coal Miners.—*J. Indust Hyg*, **11,** 3.

VERNON, H. M. and VERNON, M. D. (1928) · The Physical and Physiological Effects of Panel Heating.—*Domestic Engineering.* **48,** 101

VERNON, M. D. (1926): On Certain Effects of Long Spells of Repetitive Work.—*Brit. J. Psych.*, **16,** 3.

WARNER, E. C., and HAMBLY, W. D. (1925): An Investigation into the Physiological Basis of the U-tube Manometer Test.—*Guy's Hosp. Rep.*, July, 1925.

WESTON, H. C. (1927): The Relation between Illumination and Efficiency in Fine Processes, with special reference to the Lighting of Printing Works.—*Illum. Engineer*, **20,** 221.

WESTON, H. C. (1927): Light and Vision in Industry.—*Rep. Internat. Ass. for Study of Human Relations and Conditions in Industry* (Baveno), 1927.

WILSON, D. R. (1921): Some Effects of Environment on Efficiency and Safety.—*J. Roy. San. Inst.*, **42,** 3.

WILSON, D. R. (1921): The Work of the Industrial Fatigue Research Board, and its Applications to Industry.—*J. Roy. Soc. Arts*, **70,** 3660.

WILSON, D. R. (1923): On Some Recent Contributions to the Study of Industrial Fatigue.—*J. Roy. Stat. Soc.*, **86,** 4.

WILSON, D. R. (1923): International Co-operation in the Study of Industrial Psychology and Physiology.—*International Labour Office, Studies and Reports, Sec. F., No.* 9.

WILSON, D. R. (1924): Some Observations on Industrial Lighting.—*J. Ind. Hyg*, **5,** 10.

WILSON, D. R. (1924): Man in Relation to Production.—*First World-Power Conference*, **412.**

WILSON, D. R. (1929): Fatigue Research and its Application in the Factory.—*Report of Tenth Annual Conference on Industrial Welfare.*

WILSON, D. R. (1929): De quelques recherches récentes entreprises en Grande-Bretagne sur le facteur individuel dans les causes d'accidents —*Rev. de la Science du Travail*, **1,** 3.

WYATT, S. (1925): The Effect of Atmospheric Conditions on Health and Efficiency (with special reference to the Cotton Industry).—*J. Ind. Hyg.*, **7,** 7.

WYATT, S. (1927): An Experimental Study of a Repetitive Process.—*Brit. J. Psych*, **17,** 3.

WYATT, S. (1927): Machine Speeds and Output.—*J. Nat. Inst. Indust. Psych.*, **3,** 8.

WYATT, S. (1928): Causes of Irritation in Industry.—*Empire Review*, Oct., 1928.

WYATT, S., and WESTON, H. C. (1920): A Fatigue Test under Industrial Conditions.—*Brit. J. Psych.*, **10,** 4.

YATES, E. M. (1928): Experimental Work upon Transfer of Training —*Report of British Association.* Glasgow, p. 607 (Abstr.).

Printed by H.M S.O Press, Harrow

WESTON, H. C. (1927): Light and Vision in Industry.—*Rep. Internat. Ass. for Study of Human Relations and Conditions in Industry* (Baveno), 1927.

WILSON, D. R. (1921): Some Effects of Environment on Efficiency and Safety.—*J. Roy. San. Inst.*, **42,** 3.

WILSON, D. R. (1921): The Work of the Industrial Fatigue Research Board, and its Applications to Industry.—*J. Roy. Soc. Arts*, **70,** 3660.

WILSON, D. R. (1923): On Some Recent Contributions to the Study of Industrial Fatigue.—*J. Roy. Stat. Soc.*, **86,** 4.

WILSON, D. R. (1923): International Co-operation in the Study of Industrial Psychology and Physiology.—*International Labour Office, Studies and Reports, Sec. F., No.* 9.

WILSON, D. R. (1924): Some Observations on Industrial Lighting.—*J. Ind. Hyg*, **5,** 10.

WILSON, D. R. (1924): Man in Relation to Production.—*First World-Power Conference*, **412.**

WILSON, D. R. (1929): Fatigue Research and its Application in the Factory.—*Report of Tenth Annual Conference on Industrial Welfare.*

WILSON, D. R. (1929): De quelques recherches récentes entreprises en Grande-Bretagne sur le facteur individuel dans les causes d'accidents—*Rev. de la Science du Travail*, **1,** 3.

WYATT, S. (1925): The Effect of Atmospheric Conditions on Health and Efficiency (with special reference to the Cotton Industry).—*J. Ind. Hyg.*, **7,** 7.

WYATT, S. (1927): An Experimental Study of a Repetitive Process.—*Brit. J. Psych*, **17,** 3.

WYATT, S. (1927): Machine Speeds and Output.—*J. Nat. Inst. Indust. Psych.*, **3,** 8.

WYATT, S. (1928): Causes of Irritation in Industry.—*Empire Review*, Oct., 1928.

WYATT, S., and WESTON, H. C. (1920): A Fatigue Test under Industrial Conditions.—*Brit. J. Psych.*, **10,** 4.

YATES, E. M. (1928): Experimental Work upon Transfer of Training—*Report of British Association.* Glasgow, p. 607 (Abstr.).

Printed by H.M S.O Press, Harrow